DOUBLE NUMBER

VOL. 41 SEPTEMBER, 1925 Nos. 1 & 2

JOURNAL

OF THE

Elisha Mitchell Scientific Society

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ISSUED QUARTERLY

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The Elisha Mitchell Scientific Society

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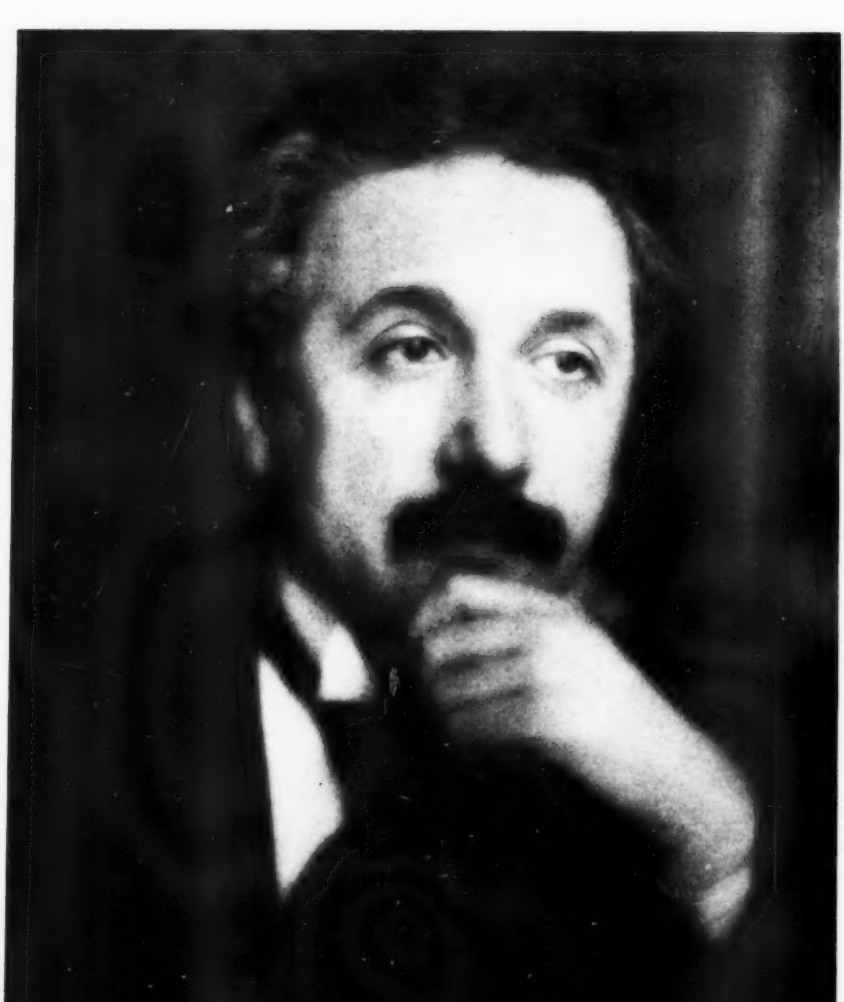
JOURNAL OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY—Quarterly. Price, $3.00 per year; double numbers, $1.50. Direct all correspondence to the Permanent Secretary, at the University of North Carolina, Chapel Hill, N. C.

In addition to original papers on scientific subjects, this Journal publishes the Proceedings of the Elisha Mitchell Scientific Society, and the Proceedings of the North Carolina Academy of Science, as well as abstracts of papers on scientific subjects published elsewhere by members of the Faculty of the University of North Carolina.

PUBLISHED FOR THE SOCIETY
BY THE
UNIVERSITY OF NORTH CAROLINA PRESS



ALBERT EINSTEIN

JOURNAL

OF THE

Elisha Mitchell Scientific Society

Volume 41 September, 1925 Nos. 1 & 2

CONSTITUTION OF THE NORTH CAROLINA ACADEMY OF SCIENCE

(*Revised to date*)

ARTICLE I

NAME AND OBJECT

Section 1. The name of this organization shall be the "North Carolina Academy of Science."

Section 2. The objects of the Academy shall be to promote study and scientific research and to furnish, so far as practicable, a means of publication of such articles as may be deemed worthy.

ARTICLE II

MEMBERSHIP AND DUES

Section 1. Any person actively interested in science or the promotion of science, may, upon nomination by two members, be elected a Member of the Academy by a majority vote of the Executive Committee, and shall be entitled to all privileges of the Academy.

Section 2. The initiation fee shall be $2.00, payable in advance, and there shall be no annual dues for the first year.

Section 3. The annual dues for old members shall be $2.00, and any person in arrears at the date of the annual meeting forfeits all privileges of the Academy.

Section 4. Any public spirited person donating one hundred dollars or more to the Academy may be elected a Patron of the Academy and shall be entitled to full privileges of membership.

ARTICLE III

OFFICERS

Section 1. The officers of the Academy shall be a President, Vice-President, Secretary-Treasurer, and an Executive Committee of six including the President, Vice-President, and Secretary, of which three shall constitute a quorum. All officers shall be elected annually, by ballot, by majority vote.

Section 2. The duties of all officers shall be such as usually pertain to such positions. The term of office shall begin with the adjournment of the meeting at which the elections are held and shall expire with the adjournment of the next regular annual meeting.

ARTICLE IV

MEETINGS

Section 1. The time and place of all meetings shall be determined by the Executive Committee, but there shall be at least one meeting annually for the presentation and discussion of papers, and at least one business meeting annually.

Section 2. Two weeks notice shall be given of all meetings, and those present at such meetings shall constitute a quorum.

ARTICLE V

PUBLICATIONS

Section 1. The official organ of the Academy shall be the Journal of the Elisha Mitchell Scientific Society, published at the University of North Carolina. The Editor of the Journal and the Secretary of the Academy shall compose the editorial board for the Academy, subject to the general control of the Executive Committee of the Academy.

ARTICLE VI

AMENDMENTS

Section 1. This constitution may be amended by a two-thirds vote of those present at any regular meeting: Provided, that such amendments be submitted in writing to the Executive Committee at least two weeks before the meeting at which action is to be taken.

BY-LAWS

1. The Executive Committee shall fill all vacancies occurring between meetings of the Academy.

2. Upon the written request of three or more members, the Secretary shall call a meeting of the Executive Committee, to consider such matters as may be laid before it, said meeting to take place within ten days from the time the request is submitted.

3. All elections to membership which take place subsequent to the annual meeting for the presentation of papers, shall apply to the following *calendar year*, and no initiation fee can be collected for the year of such election. All elections to membership, which take place at or before the annual meeting for the presentation of papers, shall apply to the calendar year in which the election takes place, and the initiation fee shall be collected accordingly.

4. The application for membership shall be accompanied by the initiation fee ($2.00), the same to be returned to the applicant should he not be elected.

5. Yearly dues for old members regularly become payable on October 1st of each year.

6. The Secretary-Treasurer, during his term of Office, shall not be liable for annual dues, and his necessary expenses in attending the regular meetings shall be defrayed from the treasury of the Academy.

OFFICERS OF THE NORTH CAROLINA ACADEMY OF SCIENCE, 1902–1926

1902

President.....W. L. Poteat
Vice-President.....T. G. Pearson
Secretary-Treasurer.....F. Sherman, Jr.

1903

President.....C. M. Edwards
Vice-President.....C. E. Brewer
Secretary-Treasurer.....F. Sherman, Jr.

1904

President.....Chas. Baskerville
Vice-President.....J. I. Hamaker
Secretary-Treasurer.....F. Sherman, Jr.

1905

President.....F. L. Stevens
Vice-President.....J. F. Lanneau
Secretary-Treasurer.....F. Sherman, Jr.

1906

President.....J. F. Lanneau
Vice-President.....Tait Butler
Secretary-Treasurer.....F. L. Stevens

1907

President.....Collier Cobb
Vice-President.....J. L. Lake
Secretary-Treasurer.....F. L. Stevens

1908

President.....T. G. Pearson
Vice-President.....W. C. Coker
Secretary-Treasurer.....E. W. Gudger

1909

President.....Tait Butler
Vice-President.....J. J. Wolfe
Secretary-Treasurer.....E. W. Gudger

1910

President.....W. C. Coker
Vice-President.....W. H. Pegram
Secretary-Treasurer.....E. W. Gudger

1911

President.....W. H. PEGRAM
Vice-President.....W. S. RANKIN
Secretary-Treasurer.....E. W. GUDGER

1912

President.....H. V. WILSON
Vice-President.....W. A. WITHERS
Secretary-Treasurer.....E. W. GUDGER

1913

President.....C. S. BRIMLEY
Vice-President.....J. F. LANNEAU
Secretary-Treasurer.....E. W. GUDGER

1914

President.....F. SHERMAN, JR.
Vice-President.....Z. P. METCALF
Secretary-Treasurer.....E. W. GUDGER

1915

President.....J. J. WOLFE
Vice-President.....A. H. PATTERSON
Secretary-Treasurer.....E. W. GUDGER

1916

President.....A. S. WHEELER
Vice-President.....W. A. WITHERS
Secretary-Treasurer.....E. W. GUDGER

1917

President.....F. P. VENABLE
Vice-President.....H. C. BEARDSLEE
Secretary-Treasurer.....E. W. GUDGER

1918

President.....W. A. WITHERS
Vice-President.....J. H. PRATT
Secretary-Treasurer.....E. W. GUDGER

1919

President.....E. W. GUDGER
Vice-President.....H. B. ARBUCKLE
Secretary-Treasurer.....B. CUNNINGHAM

1920

President.....A. H. PATTERSON
Vice-President.....R. N. WILSON
Secretary-Treasurer.....R. W. LEIBY

1921

President.....Z. P. METCALF
Vice-President.....J. M. BELL
Secretary-Treasurer.....R. W. LEIBY, Acting C. S. BRIMLEY

1922

President.....J. L. LAKE
Vice-President.....J. H. PRATT
Secretary-Treasurer.....B. CUNNINGHAM

1923

President.....A. HENDERSON
Vice-President.....H. B. ARBUCKLE
Secretary-Treasurer.....B. CUNNINGHAM

1924

President.....C. M. HECK
Vice-President.....J. P. GIVLER
Secretary-Treasurer.....BERT CUNNINGHAM

1925

President.....H. B. ARBUCKLE
Vice-President.....LULA G. WINSTON
Secretary-Treasurer.....BERT CUNNINGHAM

1926

President.....J. P. GIVLER
Vice-President.....J. O. HALVERSON
Secretary-Treasurer.....BERT CUNNINGHAM

PROCEEDINGS OF THE TWENTY-FOURTH ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE

HELD AT STATE COLLEGE, RALEIGH, N. C.,
MAY 1 AND 2, 1925

The twenty-fourth annual meeting of the North Carolina Academy of Science was held at State College, Raleigh, May 1, and 2, 1925. The meeting was one of the best attended ever held by the Academy. The program began promptly as scheduled, with President Arbuckle in the chair. Reading of papers proceeded until 12:45, when the following committees were appointed.

Nominating—A. S. Wheeler, C. S. Brimley, Z. P. Metcalf.

Resolutions—W. L. Porter, P. O. Schallert, H. L. Blomquist.

Auditing—J. L. Lake, J. M. Bell, J. F. Dashiell.

The Academy adjourned for luncheon with State College as host. After luncheon groups were guided through the laboratories of State College where everything was in full action. Members of the Academy as well as other visitors gained a keener appreciation of the work of State College by this courtesy.

The reading of papers was resumed at 2:30 p.m., and continued until 4:45 when the Academy went into business session. The minutes of the preceding meeting were approved as printed in the JOURNAL. Reports of committees were called for and their reports follow.

The Committee on Constitution reported that the constitution has been brought down to date, and recommended the printing of the revised constitution as a part of this year's Proceedings. The report of the committee was adopted.

The Committee on Reorganization reported as follows:

The Committee on the organization of sections of the North Carolina Academy of Science which was continued at the last meeting reports as follows:

1. Members sending a title to the secretary of the Academy shall indicate whether they prefer the paper to be presented before the general Academy or before a separate technical group. A brief abstract showing the suitability of the paper for the program indicated should accompany the title.

2. In case a sufficient number of titles of a very technical nature are sent to the secretary of the Academy he shall have the power to arrange such separate group programs for the presentation of these technical papers as shall appear necessary.

3. When the program of the Academy carries a sufficient number of technical papers to justify the secretary in arranging such groups, the president of the Academy shall appoint a temporary chairman and secretary for the separate technical groups. It shall be the duty of the temporary secretary of the group to report to the secretary of the Academy at the close of the meeting the titles of papers presented before the group.

4. Members shall have the right of appealing to the executive committee in case of disagreement with the secretary of the Academy as to the placing of the titles of papers on the program.

5. The present affiliation of the North Carolina section of the American Chemical Society with the Academy is not to be in any way altered by the foregoing resolutions.

The report was adopted without discussion.

The Committee on Natural Resources had no formal report, but Dr. Coker, speaking for the committee, gave some suggestions. The committee was continued and in matters pertaining to conservation was given power to act in the name of the Academy. The committee consists of W. C. Coker, chairman, Z. P. Metcalf, H. L. Blomquist, B. W. Wells, J. P. Givler and J. S. Holmes.

The Committee on Nature Study Pamphlets reported through its chairman, Dr. H. L. Blomquist, that certain investigations had been made, but due to uncertainty of the scope of the committee, no definite action had been taken. The committee was continued, and instructed to prepare samples of pamphlets, which should be submitted to the State Department of Education for publication, provided the department sees fit.

Dr. Z. P. Metcalf, the Academy's representative on the Council of the American Association, made a brief report of the new proposal of "affiliation." Discussion of the problem was deferred until after the report of the Executive Committee.

Dr. B. W. Wells reported for the lecture unit of the Publicity Committee. But few lectures have been staged through this division due to several factors:

(1) There are but few members who have submitted titles to the chairman.

(2) There have been practically no calls from schools upon the chairman for such lectures.

(3) This feature is provided for by the "Lecture Bureaus" of various institutions.

There was considerable discussion of the project and the feeling was expressed that this was entirely too big a project to be undertaken by the Academy at this time. The lecture unit was continued.

Dr. B. Cunningham reported for the newspaper and loan units. About 125 newspapers received programs, statement of purposes, etc., of the Academy. A number used them as bases for articles. Apparently this meeting has received greater attention than any preceding meeting. Thanks should be given to Mr. S. S. Bost and Miss Susan Iden who covered these meetings in a splendid manner. In regard to the loan unit, it was found that the State Department of Education, through its visual education group could not finance the lantern slide loans. However, a number of personal loans of slides had been made by Dr. Cunningham.

The Legislative Committee was not represented at the meeting, so no report was forthcoming.

The Auditing Committee reported the records of the treasurer to be accurate and satisfactory. The report was adopted and the secretary was instructed to print the financial statement. The financial statement follows:

Financial Statement

Receipts		Expenditures	
Balance on hand	$142.68	Postage	$19.00
Dues 1923-24	66.00	Stenographer	40.00
Dues 1924-25	283.10	Secretary Commission	24.50
Chemists Program	5.00	Secretary Dues Refund	2.00
S. P. E. E. Program	2.00	E. M. Journal	175.00
Physicists Program	2.00	Multigraphing	10.00
		Programs	20.00
	$500.78	Telephone	.65
			291.15
		To balance	209.63
			$500.78

Assets		Liabilities	
Balance checking account	$209.63	E. M. Journal	$175.00
Balance savings account	340.36	Secretary Commission	11.30
Chemists Program	5.00		
			186.30
	$554.99	To balance	$368.69

Comparison	1923-24	1924-25
Savings account	$326.55	$340.36
Checking account	142.68	209.63
	469.23	$549.99
To balance	80.76	
	$549.99	

The above report was made as of April 25th.

Submitted by:
BERT CUNNINGHAM, *Secretary-Treasurer.*

Audited by:
JAS. L. LAKE,
JAMES M. BELL,
J. F. DASHIELL.

The Committee on High School Science reported as follows:

Your committee met April 30, 1925, in the office of Prof. C. M. Heck of State College, with Messrs. Cunningham, Heck, Highsmith and Wilson present.

The committee wishes to report progress in general and the attainment of some of the particular objectives. Among these we wish to report that a separate High School Science unit has been formed in the North Carolina Education Association, which continues to function. In addition science units have been set up in the six regional districts of the North Carolina Educational Association and these units have taken a definite part in the annual program of their several district meetings. It is recommended that the Academy continue to assist in the work of these district meetings.

The plan recommended is as follows:

The chairman of this committee is directed to assign to each member of the committee the duty of representing the Academy at some one of these district meetings. It shall be the duty of the person so assigned to coöperate with the chairman of the science group in his particular district and to render any service possible.

It is recommended that Dr. Wells be substituted on the committee in place of Mr. Roller. It is recommended further that the members of this committee be directed to meet at a date just prior to the annual

meeting of the North Carolina Educational Association and make a report of their work to the committee.

In view of the fact that the North Carolina Educational Association has recently inaugurated an employment agency for teachers and further that the State Department of Education has installed something of the same sort, it is recommended that the matter of a bureau of information for science teachers be dropped for the present.

We wish to acknowledge the receipt of a letter from the State Superintendent of Education expressing his interest and willingness to cooperate in the matter of visitation and inspection of science work in High Schools, by delegated members of this Academy. We wish to thank Supt. Allen for the coöperation of the State Department of Education.

It is recommended that the State Department of Education be requested to require two full unit courses in science for graduation from High School.

Respectfully,

J. N. COUCH,
C. M. HECK,
J. H. HIGHSMITH,
R. N. WILSON,
B. CUNNINGHAM,
Committee.

The report was adopted and the committee continued.

The Executive Committee Reported as follows:

The Executive Committee, with Miss Lula G. Winston absent, met at noon, May 3rd to outline some of the policies for the ensuing year.

It was unanimously agreed that no privileges such as extension of time, etc., for the presentation of papers, would be granted to any member of the Academy or to any visitors by the Executive Committee, and that the granting of any such privileges by the Academy would be discouraged by the committee.

It was unanimously agreed that the secretary should be authorized to expend as much as $100 on stenographic aid in connection with the routine of his office and the additional work in publicity.

It was also agreed that the secretary should call for a résumé or an abstract of papers to be presented to the Academy at the time titles are requested, in order that he may use more "discretion" in placing

the papers. It was also agreed that a proposal would be made at the next Academy meeting, requiring such resumé or title before papers may be placed on program; such resumé or abstract not to be published without the permission of the author.

Meeting of the Executive Committee of the North Carolina Academy of Science was held at State College, Thursday night, April 30, 1925, with A. Henderson absent. The following recommendations were adopted for presentation to the Academy.

1. That abstract or full papers in order to appear in the Proceedings of the Academy must be submitted to the Secretary not later than the close of the Annual Meeting.
2. That a flat membership fee of $2.00 be collected by the Academy treasurer from each member, regardless of whether he be a member of the A. A. A. S.
3. That the 50¢. allowance from the A. A. A. S. be applied to the general funds for the present.
4. That the savings fund be increased to $350 and the income thereof be used to establish a prize in science for high school students, said prize to be administered by a standing committee of the Academy. The committee as appointed by the chair: J. P. Givler, C. M. Heck, W. W. Wood.
5. That the Academy send greetings to the Virginia Academy which is now in session.
6. That all bills be paid as passed by the Auditing Committee.
7. That the financial report be passed to the auditing committee, and if found correct published.

The following were then elected to membership.

Appleby, J. M., Assistant in Chemistry, Davidson College
Crockford, H. D., Instructor in Chemistry, University
Dickert, H. A., Dept. Agriculture, Raleigh
Edminster, T. H., Asst. Professor of Chemistry, University
Elmore, K. L., Instructor in Chemistry, Duke University
Foster, N. B., Dept. Physics, North Carolina College for Women
Johnson, Mary M., Assoc. Professor of Chemistry, Meredith College
Lalor, Marjorie J., Dept. Biology, Peace Institute
Lay, Rev. George W., Beaufort, N. C.
Lineberry, R. A., Grad. Student, University
Nooe, Sarah, Teacher of Chemistry, Oxford
Patterson, P. M., Asst. in Biology, Davidson College
Penny, J. T., Teaching Fellow in Zoology, University
Plyler, E. K., Dept. Physics, University

Powell, Martha, Teacher of Chemistry, Wilson
Rice, F. E., Prof. Biol. and Agr. Chemistry, State College
Robert, Nan, Dept. Biology, Flora McDonald College
Satterfield, G. H., Dept. Chemistry, State College
Seiwell, H. R., Asst. in Geology, University
Shore, Dr. C. A., State Dept. Public Health, Raleigh
Swartz, J. H., Asst. Professor of Geology, University
Vollmar, Rev. Dominic, Dept. Chemistry, Belmont Abbey College
Wierda, J. L., Dept. Biology, Duke University
Williams, J. H., Graduate Student, State College
Williams, V. M., Associate in Dairy Research, State College
Wilson, J. S., Graduate Student, State College
Wray, D. L., Student, State College

The report was adopted section by section and finally adopted as a whole.

The Nominating Committee submitted the following slate for the coming year.

President—J. P. Givler, N. C. C. W.

Vice-President—J. O. Halverson, State Dept. Agriculture.

Secretary-Treasurer—B. Cunningham, Duke University.

New member of Executive Committee—H. B. Arbuckle. The other members of the Executive Committee are C. M. Heck and A. Henderson.

The report of the Committee was adopted and the Secretary instructed to cast the ballot.

The Resolutions Committee submitted the following report:

1. With sorrow we note the death of two of the Academy's oldest and most respected members, Prof. W. A. Withers, of State College and Prof. R. S. Pritchard, of Wake Forest, both of them of the department of chemistry in their institutions. In their death not only does the Academy suffer a great loss, but the cause of scientific education in North Carolina loses two skilled and devoted exponents who have exerted a marked influence on generations of the young men of the South.

We extend to their families and friends our sincere sympathy.

To Prof. Metcalf of State College, we would also express our sympathy because of the death of his father.

2. We express our thanks to the Translux Company for the use of

their projection machine and screen and for the services of their obliging demonstrator, Mr. H. T. Hassee.

3. To State College, its authorities, staff and students, we express our keen appreciation of their courtesies and the hospitability that has made our spring meeting so delightful.

W. L. PORTER,
P. O. SCHALLER,
H. L. BLOMQUIST.

The report was adopted by a rising vote.

The Academy was thrown open for further business, and as there was none the Academy adjourned to meet at 8:15 p.m. In the interim the Academy enjoyed a "get-together" supper at the College Y.

At 8:15 Dr. C. C. Taylor of State College. in the absence of President E. C. Brooks, gave a word of welcome to the Academy, and then introduced the President of the Academy, Dr. H. B. Arbuckle, who gave an interesting address on "The Life and Habits of the Honey Bee." After this address a social hour, and refreshments were enjoyed by all.

The Academy met in separate sections on Saturday morning at 9:00 o'clock. Due to manipulation of one kind and another the programs of all groups were finished and the Academy adjourned in time for all to join in the final luncheon as guests of State College.

The following papers were presented. (Those marked with an * appear in full in this JOURNAL, those with an x are abstracted. No abstracts have been received for those unmarked.)

Results of the Plankton Studies of Chesapeake Bay. BERT CUNNINGHAM, ET AL.

**Variation of Protein Content of Corn.* H. B. ARBUCKLE AND O. J. THIES, JR.

x*A Study in the Direction-Sense of Animals.* J. F. DASHIELL.

Development of Some Disc Fungi. F. A. WOLF.

The Physiography of Brazos County, Texas. E. O. RANDOLPH.

**Two Rare Types of Abnormality in Cotton Seeds.* S. G. LEHMAN.

x*Morphological Ecology of Certain Savannah Plants.* C. F. WILLIAMS.

x*Results of Soft Pork Investigations.* J. O. HALVERSON AND E. H. HOSTETLER.

**Seasonal Catch of Snakes at Raleigh.* C. S. BRIMLEY.

New Ideas Concerning Mass. A. H. PATTERSON. (By title.)

Some Homoptera From Cuba. Z. P. METCALF. (By title.)

x*Some Properties of Ice Crystals.* E. K. PLYLER.

**Meteorological Inquiries from the Viewpoint of 1795.* L. A. DENSON.

Some Factors Affecting the Growth of Young Rats. F. W. SHERWOOD.

New Water Molds from the Soil. W. C. COKER AND J. V. HARVEY.

The Present Status of the High School Science Program. C. M. HECK.

x*An Oil-Bearing Soft Pelite from Ontario, Canada.* COLLIER COBB.

Methods of Investigation in Social Psychology. C. C. TAYLOR. (By title.)

The Structure of the Atomic Nucleus. A. H. PATTERSON. (By title.)

**An Oil-bearing Shale of North Carolina.* F. C. VILBRANDT.

Models of Elementary Crystal Structure from X-ray Evidence. OTTO STUHLMAN, JR.

Riccia sorocarpa, Bisch. H. L. BLOMQUIST.

x*X-rays and Their Biological Effects.* L. H. SNYDER.

x*The Effect of Heat on the Viscosity of Some of Our Familiar Lubricating Oils.* H. B. ARBUCKLE.

x*Loessal Soil and the World's Food Supply.* COLLIER COBB.

x*The Excitation of the O-energy Levels in Tungsten by Electron Bombardment.* O. STUHLMAN, JR.

The Rate of Rotation of a Foucault Pendulum. K. B. PATTERSON.

Observations on Conjugation in Spirogyra from Living Material. J. N. COUCH.

**Investigation on the Germinating and Heating of Cotton Seed in Warehouse Storage.* E. E. RANDOLPH.

The Development of the Periblast in the Teleosts. J. T. PENNY AND W. R. EARLE.

x*A Simple Proof of the Law that the only Possible Periods of Crystal Symmetry are 1, 2, 3, 4, and 6.* J. H. SWARTZ.

**Iron Coloration in Rocks and Minerals.* G. R. MACCARTHY.

x*Structural Conditions in the West Central Appalachians.* W. F. PROUTY. (By title.)

**Progress on State Insect Survey, with Comparative Data on Other Animal Groups.* F. SHERMAN.

x*Brief Notice of a New Method for the Radioactive Determination of the Age of the Earth.* J. H. SWARTZ

x*Brief Notice of a New Method of Stratigraphic Correlation.* J. H. SWARTZ.

x*The Triassic Basin West of Raleigh.* W. F. PROUTY. (By title.)

x*General Properties of Involution in N-ary Algebra.* E. T. BROWNE,

Regularity of Quadratic Transformations of Infinite Series. G. M. ROBISON.

x*Notes on Osculating Hyperboloids.* J. W. LASLEY.
Graphical Solution of Cubics. K. B. PATTERSON.

The following papers were presented to the North Carolina section of the American Chemical Society.

x*Studies on the Nutritive Value of the Peanut: The Effect of Peanut Proteins on Growth of Pigs.* J. O. HALVERSON AND EARL HOSTETLER.
Nitration of P-cymene. A. S. WHEELER AND C. R. HARRIS.
The Evaluation of Lubricating Oils. F. C. VILBRANDT AND R. M. BYRD.
**Recent Developments in Chemical Industries of North Carolina.* F. C. VILBRANDT.
An Investigation of the Deodorizing and Decolorizing of Fish Oils. E. E. RANDOLPH AND G. L. ARTHUR.
Oxidation of Sulfur Dioxide with Permanganate. F. C. VILBRANDT AND H. A. DICKERT.
Latent Heat of Fusion of Some Nitrotoluenes. H. D. CROCKFORD.
E. M. F. Studies on Battery Metals. F. C. VILBRANDT AND R. R. SUGGS.
The Refractometer as a Means of Determining Dry Matter in True and Colloidal Solutions with Particular Application to Foods. F. E. RICE.
The Determination of Phosphorus in Steel. F. C. VILBRANDT AND W. M. MEBANE.
The Chemist in the Laundry. F. C. VILBRANDT AND W. C. QUINBY.

The following abstracts have been received:

A Study in the Direction-Sense of Animals. J. F. DASHIELL.

Incidental findings in previous work with animals have been confirmed by the use of a specially planned maze. It was devised so that a variety of pathways led from entrance to exit. Each of the white rats used quickly learned to find its way to the exit without error although by a wide variety of routes in trial after trial. As all the known objects that might serve as direction-indicators were eliminated or checked, the problem arises as to just how the animal is able to maintain a general orientation while going through a series of right-left turns that vary from trial to trial. It is suggested that some kind of motor set might be established as the animal first enters the maze, and then as it turns

to right or to left some compensatory mechanism maintains a tendency to left or to right until such turn is actually made. References are made to the sensitiveness of the white rat to proprioceptive stimulations, and to different well-known compensatory reflexes.

Morphological Ecology of Savannah Plants. I. Campulosis aromaticus. C. F. WILLIAMS.

The savannah community consists of open grassland growing on extremely level, poorly drained and aerated soil, which is apparently well supplied with water. However most of the vegetation exhibits a considerable degree of xerophytism. Thus this habitat is probably physiologically dry. *Campulosis aromaticus*, which is one of the dominant grasses, shows extreme development of xerophytic characters. It forms a deep fibrous base composed of the old leaf bases, inside of which an annual corm develops. The culm grows 3 or 4 feet tall and bears the spike at a considerable angle. The spikelets are appressed along the lower side and have oil glands. The roots have well developed aeriferous tissue. The leaf is of the ridge and furrow type and curls when the cells in the valleys loose their turgor from excessive transpiration. The upper surface is densely covered with short simple trichomes, and the lower has a shiny cuticle. The stomata are protected in the valleys. The chlorenchyma is of two types, each at right angles with the surface of the leaf. One type consists of pseudo-palisade cells with invaginated walls and containing the usual chloroplasts, the other consists of large cells with thick pitted walls and containing very large netted chloroplasts, suggesting a division of labor of the photosynthetic function. Much mechanical tissue is present as well as peculiar thick walled cells in the epidermis. Both collateral and concentric bundles are present.

Results of Soft Pork Investigations. J. O. HALVERSON AND EARL HOSTETLER.

The effect was studied of various methods of feeding hardening and softening feeds, especially the peanut, and Brewer's rice which consists chiefly of starch with very little ether extract.

Equal total amounts of oil were fed individually throughout to each pig. To some were given equivalent amounts of starch (as Brewer's rice) at the same time. To others, the oil-feeding period was followed by the Brewer's rice. All pigs consumed the same amount of peanut oil and equivalent amounts of starch throughout the experiment according to the energy relation of fat to starch, 2.24.

The hardening period of Brewer's rice following peanuts resulted in a harder carcass in every instance.

All pigs throughout these experiments were individually fed a "standard" ration of equal energy, total digestible protein and total oil intake.

The work indicates that to harden a peanut-fed hog the pig must consume a starch equivalent to $2\frac{1}{4}$ to $2\frac{1}{2}$ times the total amount of oil consumed.

Some Properties of Ice Crystals. E. K. PLYLER.

Many of the properties of ice crystals have been studied. It has been found, when consideration is made for temperature, that ice crystals have properties similar to those of other crystals. In this work a study of the growth of the individual crystals in a solid piece has been made. A review of the theory of Chamberlain is given and it is shown that his theory does not apply to a solid piece of ice.

The writer has found that the region between the ice crystals has a much higher absorption of infra red light than the ice itself. Thus when light is incident upon the ice the melting first takes place between the crystals. This fact has been explained by some workers as due to salts that existed in the water before the ice was formed. However, about the same action is obtained when distilled water is frozen.

The thickness of the boundary between the individual crystals were measured in many cases. Some of these were found to be less than 0.0008 cm. On account of melting which took place due to the infra red radiation it was difficult to find the actual thickness of this layer. Due to the small volume of this layer it is easily melted by radiation. Then we have the crystals surrounded by a layer of water. Since the larger crystals will heat up more slowly or they have a greater heat capacity than the smaller ones, they are able to freeze more of the water than the smaller crystals. Also the vapor pressure is greater over a small crystal than over a large one, due to the greater curvature of the smaller crystal, and this will be an added effect to the one previously mentioned. There is also the possibility of this explanation of crystal growth having some influence in the larger problem of glacial motion.

An Oil-Bearing Soft Pelite from Ontario, Canada. COLLIER COBB.

This substance burns like bitumen, and is made up of the leaves of *Salix*, *Vaccinium*, and other genera which still grow in the same general region and in northern Asia, and of the spores of a number of flowerless

plants with essentially the same distribution, and extending well down into the main island of Japan (Honshiu).

X-Rays and their Biological Effects. L. H. SNYDER.

Recent experiments on the possibility of inducing heritable modifications in animals by treatment with x-rays, radium, etc., have given conflicting results, some few being positive, and some negative. In this experiment, the germ cells of male rats were exposed to x-rays for varying dosages, and the offspring raised. No effect was found on the treated rats, except the occurrence of a sterility period, which can be made only temporary by the proper dosage. Offspring raised from such rats after the sterility period have been inbred to the fifth generation without any signs of abnormalities, lessened vigor or loss of fertility. The soft rays, of long wave length, are the effective rays in causing the temporary sterility. It is found that x-rays effect actively growing tissue, but not tissue which is resting, or quiescent. Temporary sterility, followed by a return to full fertility, however, can very easily be induced by x-rays without harmful effects to the offspring.

Effect of Heat upon the Viscosities of Lubricating Oils. H. B. ARBUCKLE.

Most lubricating oils are advertised with certain viscosity constants which have been determined at 70°F. It is generally believed that viscosity is the most reliable index of lubricating power. Since the oil in the engine case of an automobile under ordinary working conditions shows a temperature from 125°F. to 150°F. it occurred to the author that the viscosity that should determine the value of a lubricating oil is the viscosity constant taken at these higher temperatures.

A number of the most familiar lubricating oils of medium grade were investigated and the table below gives the viscosity of five very common oils selected from a large number of oils examined.

	VISCOSITY (SCOTT) AT:				
	70°	100°	150°	200°	225°
	seconds	*seconds*	*seconds*	*seconds*	*seconds*
A	740	210	44	24.3	21.4
B	696	220	53	24	22
C	360	118	35	23.2	20
D	340	125	44	26	23
E	224	215	56	28	24

By certain tests it has been shown that an oil that is as low as 25 sec. as determined by this viscosimeter has practically no lubricating power.

The above figures show that only two oils exceed 25 sec. at 200°. This shows that none of these petroleum oils are good lubricants at 200°. One experimenter claims that the bearings in an automobile attain a temperature of 180°. This would indicate that the lubricating oils in use at present are unsatisfactory. D shows up best in the table and its initial viscosity is lowest.

Loessal Soil and the World's Food Supply. COLLIER COBB.

Time has been spent during the year in the physical analysis and microscopic examination of wheat soils from all parts of the earth, a part of the results obtained were given to the Academy of Science in this paper. The investigator has found that the great stretches of grain-producing soils, whatever their origin, are composed of finely comminuted rock material in which the component mineral particles show but little chemical change. This is equally true of glacial, loessal, and desert soils.

The Excitation of the O-energy Levels in Tungsten by Electron Bombardment. OTTO STUHLMAN, JR.

It was found that when thermelectrons liberated from a tungsten filament were accelerated and allowed to impinge on a tungsten grid maintained at a variable positive potential, secondary electrons were emitted by the grid. The number of such secondary electrons emitted were measured by means of a galvanometer in series with the grid and a plate maintained at a constant positive saturation potential.

On plotting the secondary current as a function of the accelerating voltage, acting on the primary electrons, a sudden change found in the slope of the curve at critical potentials were interpreted by the energy-quantum relation as ionization or radiation potentials. The O-energy levels so far discovered are located at energy-levels whose values of n/R are $O_2 - O_1 = 0.608$, $O_4 - O_3 = 2.96$, $O_5 = 5.20$. Corrections are made for the work function of W as equal to 4.5 volts.

A Simple Proof of the Law that the Only Possible Periods of Crystal Symmetry Are 1, 2, 3, 4, and 6. J. H. SWARTZ.

A crystal to be symmetrical must repeat its original position an integral number of times during one complete rotation about an axis of symmetry. The number of times such repetition occurs in one complete rotation is said to be the period of symmetry of the axis. If n equals the number of repetitions in 360° the angle through which the crystal is rotated between two successive repetitions is one nth of 360°. Calling this angle α, we note that, since n is integral, α must be an aliquot part of 360°.

Assume such an axis of symmetry intersected by a series of lateral axes any one of which could be brought into complete coincidence with any of the others by rotation through the angle α or a simple multiple of α. It was first shown that a plane parallel to the symmetry axis and perpendicular to a lateral axis would, when passed through *any random* raumgitter particle on the lateral axis, always intersect the next adjacent lateral axis in a raumgitter particle. Assuming such a plane passed through the first raumgitter particle on one of the lateral axes, and calling its intercept on the adjacent lateral axis b, we get:

$$\frac{1}{b} = \cos \alpha$$

By the law of the rationality of parameters b must be an integer. Assigning b all its possible integral values from 1 to ∞, it is shown that the only values of b which make α an aliquot part of 360° are 1, 2, and ∞, for which α equals 360°, 180°, 120°, 90°, and 60°. The corresponding symmetry periods of 1, 2, 3, 4, and 6 are, therefore, the only possible periods of crystal symmetry.

Brief Notice of a New Radioactive Method of Determining the Age of the Earth. J. H. SWARTZ.

There are several objections to the present radioactive methods for determining the age of the earth. (1) The amount of lead usually present is so small that it can be measured only in very highly radioactive minerals. Thus the Uranium-Lead method is available for only a very few rocks. (2) So much Helium will have escaped during the lapse of geologic ages that the Helium method, while easier, is highly inaccurate. (3) It is assumed that the radioactive matter is coeval with the rock. (4) It is assumed that no radioactive matter has been added to or abstracted from the rock since its formation. (5) It is assumed that no lead but radioactive lead is present and that none has been added or subtracted since the rock was first formed. The last three assumptions are entirely unproven, although they have given fairly accordant results in the few minerals tested so far. To determine the validity of these assumptions and thereby of the radioactive method itself it is necessary to determine the age of a great number of rocks of the same geologic horizon from as many localities as possible. This can be done only if new and more accurate radioactive methods can be devised. The purpose of the present paper is to outline a method by which it is hoped this may be accomplished.

The ratios of Uranium to Thorium and of Uranium-Lead to Thorium Lead in a given rock depend (1) on the original ratio of Uranium to

Thorium and (2) on the age of the rock. If we let N_o equal the number of atoms of the radioactive substance originally present in the rock, N equal the number remaining after time t, and ΔN equal the number which have disintegrated during the time t, we get, from the well-known equations for radioactive disintegration:

$$\frac{\Delta N}{N} = \frac{1 - e^{-\lambda t}}{e^{-\lambda t}} = e^{\lambda t} - 1$$

Letting the subscripts U and Th stand for Uranium and Thorium, we get,

$$\frac{\Delta N_U}{N_U} = e^{\lambda_U t} - 1 \quad \text{and} \quad \frac{\Delta N_{Th}}{N_{Th}} = e^{\lambda_{Th} t} - 1 \tag{1}$$

From this we get

$$\frac{\Delta N_U}{N_U} \cdot \frac{N_{Th}}{\Delta N_{Th}} = \frac{\Delta N_U}{\Delta N_{Th}} \cdot \frac{N_{Th}}{N_U} = \frac{e^{\lambda_U t} - 1}{e^{\lambda_{Th} t} - 1} \tag{2}$$

N_U and N_{Th} are measured directly. Since ΔN_u and ΔN_{th} are the two lead isotopes, radio-lead and thorium-lead, their ratio may be obtained by determining the relative intensities of their positive ray spectra by the mass-spectrograph, a method which it is hoped soon to render applicable. With this ratio known, since λ_u and λ_{th} are well-known constants, every quantity but t in equation (2) is known. The age of the rock, t, may be obtained, therefore, by solving this equation. As the solution is somewhat complex space does not permit its inclusion here.

Brief Notice of Two New Methods of Stratigraphic Correlation, with Special Reference to the Chattanooga Black Shale. J. H. SWARTZ.

Due to its stratigraphical peculiarities and lack of identifiable fossils the Chattanooga black shale has presented, for over seventy-five years, one of the outstanding problems of American geology. The present effort is an attempt to solve the question of its geological age by two new methods of correlation.

The first consists in polishing sections of the shale cut at low angles to the bedding planes, thus spreading the latter out. The bedding planes are treated with certain reagents to render them more conspicuous and their thicknesses then measured. Plots similar to those of de Geer, Antevs, and others are then made of their variations in thickness. An attempt is being made to correlate in this way the beds from different localities.

The second method consists in determining the variations in the

percentage of colloidal material present at equidistant points throughout the beds. It is believed that these percentages vary in accordance with diastrophic changes.

By applying both methods at the same time it is hoped to settle not only the question of the age of the Chattanooga shale but also to decide between the three possible causes of bedding in such fine grained shales: 1. rythmic precipitation of colloids; 2. seasonal variations; or 3. diastrophic variations.

Structural Conditions in West Central Appalachians. W. F. PROUTY.

The area of study lies between the Virginia-West Virginia line and the Alleghany Plateau and has a northwest-southeast extent of 30 miles. Observations were also made in a northeast-southwest direction of from 25 to 30 miles.

In this area the intensity of earth shortening (folding) decreases toward the west. On the east there are overturned folds with steep dips common, but toward the west not only are the dips relatively shallow but the folds tend to be symmetrical in cross-section.

The rocks exposed in this area have a total thickness of 14,000 feet. They vary in age from middle Ordovician to the Pocono sandstones of the Mississippian, and they vary in character from the massive quartzite of the Medina to the very fissil shales of the Marcellus and Genesee. In these rocks are included practically every type of sedimentary deposit and degree of competency (resistance to crushing).

All folds in the area are canoe-shaped (that is, elongate with plunging axes). They vary in size from those of only a few inches or feet up to that of the Big Ridge Syncline, which has a length of over 30 miles. All the larger folds and many of the smaller ones have secondary anticlines and synclines so that they are in reality anticlinoria and synclinoria. The anticlines are more apt to have this secondary folding than the synclines.

In the total area of about 750 square miles there are no faults of any importance, although the rocks have in many places dips of more than 70 degrees and in other places even slightly overturned conditions. There seem to be two main reasons for this great amount of folding with little or no fracture: 1. The competent beds such as the Oriskany sandstone and the Medina sandstones are each overlain and underlain by considerable thickness of relatively incompetent beds against which they have been able to cushion. This is especially true of the Oriskany. 2. The more competent of the two competent beds is the more deeply buried and as a result it more nearly reached the plastic condition during the time of folding.

Most of the larger folds show cross-folding (or irregularities in the elevation of the axis). Some of these irregularities on the larger anticlines are represented by conspicuous topographic changes.

The area as a whole has suffered a northwest-southeast crustal shortening of from 15- to 20%. This is considerably less than the average shortening of the Appalachian belt a little more to the east, and also less than the crustal shortening in the corresponding structure zone in Maryland and Pennsylvania to the northeast, or Virginia and Tennessee to the southwest.

Triassic Basin West of Raleigh. W. F. PROUTY.

The Triassic Basin (Deep River Basin) reaches its greatest width of outcrop in the cross-section between Durham and Raleigh. It is here approximately 15 miles wide. The basin is monoclinal in structure with an average dip of from ten to fifteen degrees to the southeast. The Triassic deposit is terminated on the southeast by a fault of very great throw which appears from surface indications to have a dip to the west. This basin is bordered on both the southeast and northwest sides by crystalline schists which frequently strike at considerable angle to that of the Triassic sediments. These schists are intruded by igneous rocks of much younger age and most commonly of acid character.

The fault terminating the Triassic on the east is paralleled by a zone of from a quarter to half a mile in width in which there are other lines of weakness. This fault zone is apparently the location of faults which were earlier than the one forming the contact between the schist and the Triassic. In many places in the area this old fault zone is the location of masses of vein-quartz which apparently sealed the former lines of weakness. Quartz pebbles and bowlders, worn from these deposits, are to be found in the conglomerates in different horizons in the Triassic to the west. The Deep River Basin is similar to the Connecticut Triassic Basin in respect to this older fault zone to the east of it with its quartz veins.[1]

The western border of the Deep River Triassic belt is locally faulted, but as a rule there has been little disturbance on this side of the field and the rocks exposed there belong at or near the bottom of the Newark Series while those on the east are at or near the top of the Series. We have therefore the Triassic sediments occurring at the present time in a trough whose bottom gradually deepens toward the east until it is terminated by the great eastern fault.

[1] W. L. Russell. Am. Jour. Sci. Vol. IV, Dec., 1922.

The rocks in the Triassic Basin are extremely varied. On the west there are occasional deposits of conglomerates, but on the east side of the basin they are very common. In the central portion the sediments are finer-grained as a rule, but even here pebbles up to half an inch are seen in the sandstones. The sands and the clays, or the more indurated sandstones and shales, are typically red in color. This is more especially the case toward the top and toward the bottom of the Triassic, but there are red beds even in the generally gray and buff portion of the lower center. Both wind and wave cross-bedding is common. Ripple marks and sun cracks also occur in many parts of the field. Wind faceted quartz pebbles are found more especially in the lower portion of the deposits, and locally, in about the same horizon, there occurs much petrified wood. Laminated clays in places are followed by erosional surfaces showing frequent changes of level and character of sedimentation, some in water and some on land.

The colors are not coextensive with the beds or laminae but the reds and the buffs and other iron oxide stains are more intense where clay is more common as a constituent of the rock. The colloidal clay acts as a mordant for the iron oxide. Clay-galls in gray or buff sand are frequently deep red.

If the general dip were alone considered, the width of outcrop of the Triassic is sufficient to give to the deposit a thickness of more than 15,000 feet. Some faults, in general parallel with the east border fault, are apparent and others are probably present but concealed beneath the loose surface drift. Taking these into consideration a rough estimate of the probable thickness of the Triassic gives 10,000 feet. This is not far different from estimates of thickness of the Triassic deposits made by Campbell and Kimball[2] in the Cumnock Basin to the southwest and the deposits farther north in Connecticut and Massachusetts made by various authors.

That elevation of the schists and granites and their contained quartz veins on the east side of the Triassic Basin occurred at stages during the period of sedimentation of the Triassic rocks, is clearly demonstrated by the conglomerate and fanglomerate beds which have massive and little waterworm pebbles and bowlders at different horizons close to the east side of the field, and by the fact that these beds, which originally had a steep western dip at time of formation, now have a slight eastern dip.

Intrusive diabase, chiefly in the form of dikes and sills occurs through-

[2] Deep River Coal Field of North Carolina, Bulletin 33 N. C. Geol. & Econ. Survey, 1923.

out the Triassic but is more common in the lower and in the upper portions.

General Properties of Involutions in n-ary Algebra. EDWARD T. BROWNE.

An involution is a projective correspondence of period two. Any matrix A, not itself a scalar, but whose square is a scalar, is the matrix of an involution. In this paper only *real* matrices, (i.e., matrices all of whose elements are real) are considered. Every matrix of an involution may be expressed as the product of a constant $k \neq 0$ by one or the other of the matrices A, B, where

$$A^2 = I, \; B^2 = -I,$$

where I is the matrix of the identical transformation, or the *Unit* matrix. This paper is therefore a study of matrices A, B which satisfy the above condition.

Part I

In the first part of the paper are considered matrices A, not plus or minus the Identity, which possess the property that their square is the Identity, i.e., $A^2 = I$. Properties of such matrices have been much studied. Among the well-known properties are the following:

I. If $A^2 = I$, the characteristic equation of A has no roots other than ± 1.

II. If $A^2 = I$, the characteristic equation of A cannot possess a root of multiplicity n, unless A reduces to a scalar.

III. If $A^2 = I$, and if ρ be a root of multiplicity p ($p \leqq n$) of the char. eqn. of A, then if λ be replaced by ρ in the char. matrix of A, the rank of the resulting matrix is n-p.

IV. If A, C are two matrices of the same order n such that $A^2 = I$, $C^2 = I$, a necessary and sufficient condition that there exist a non-singular matrix P such that

$$P^{-1}AP = C$$

is that the trace of the two matrices be the same.

(By "trace" we mean the sum of the terms in the principal diagonal of the matrix.)

In this paper a study is made of the transformations on such matrices A with regard to the group of all orthogonal matrices. The following very interesting properties have been found, some, at least, of which, it is believed are new.

Theorem I. If $A^2 = I$, and if the char. eqn. of A has a root of multiplicity p at $\lambda = +1$, there exists an orthogonal matrix Q such that

$$Q'AQ = M$$

where M is a matrix of the form:

$$M = \left\| \begin{array}{ccccc|c} 1 & 0 & \cdots & 0 & & a_1{}_{p+1} \cdots a_1{}_n \\ 0 & 1 & \cdots & 0 & & a_2{}_{p+1} \cdots a_2{}_n \\ \cdots & \cdots & \cdots & \cdots & & \cdots \\ 0 & 0 & \cdots & 1 & & a_p{}_{p+1} \cdots a_p{}_n \\ \hline 0 & 0 & \cdots & 0, & -1 & \cdots 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & 0 & 0 \cdots & -1 \end{array} \right\|$$

Since $A^2 = I$, M also possesses the property that $M^2 = I$; conversely, any matrix of the form M possesses the property that $M^2 = I$. The form M is called a semi-normal form of the matrix A.

Theorem II. If ρ is a root, not equal to plus or minus 1, of the char. eqn. of the symmetric matrix $\frac{1}{2}(A + A')$, then $-\rho$ is also a root of the same equation.

Theorem III. If the char. eqn. of the matrix possesses no roots other than plus or minus 1, then A is symmetric, so that $A = \frac{1}{2}(A + A')$

Theorem IV. If the char. eqn. of $\frac{1}{2}(A + A')$ possesses r pairs of roots $\rho_i, -\rho_i$ $(i = 1, \ldots, r)$ not equal to plus or minus 1, while all other roots are ± 1 there exists an orthogonal matrix κ such that

$$\kappa' A \kappa = N,$$

where N is a matrix of the form:

$$N = \left\| \begin{array}{cccccccc} \rho_1, & \sigma_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -\sigma_1, & -\rho_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & \rho_2 & \sigma_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & -\sigma_2 & -\rho_2 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & \rho_r & \sigma_r & 0 & 0 \\ 0 & 0 & 0 & 0 & -\sigma_r & -\rho_r & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 0 & +1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{array} \right\|$$

Here $\rho_i{}^2 = 1 + \sigma i^2$ $(i = 1 \cdots r)$

Theorem V. If A, B are two matrices of the same order n such that $A^2 = I$, $B^2 = I$, a necessary and sufficient condition that there exist an orthogonal matrix R such that

$$R'AR = B$$

is that the char. eqns. of the two matrices $\frac{1}{2}(A + A')$, $\frac{1}{2}(B + B')$ be the same.

Theorem VI. The number of roots different from ± 1 of the char. eqn. of the matrix $\frac{1}{2}(A + A')$ is exactly equal to the rank of the skew-symmetric matrix $(A - A')$.

Theorem VII. If the char. eqn. of A possesses a root of multiplicity p at $+1$, there exists an orthogonal matrix S such that

$$S'AS = \bar{N}$$

where $\overline{N}$ is a matrix of the form:

$$\overline{N} = \begin{Vmatrix} 1\,0\,. & 0\,c_1\,0\,.\,.\,0 \\ 0\,1\,.\,. & 0\,0\,c_2\,.\,.\,0 \\ 0\,0\,.\,. & 1\,0\,0\,.\,.\,.\,0 \\ 0\,0 & 0\,-1\,0\,.\,0 \\ 0\,0 & 0\,0\,0 \quad -1 \end{Vmatrix}$$

The c's in the upper right hand corner of N are not arbitrary. In fact they are definitely determined except for sign and except for the order in which they occur. If the char. eqn. of the matrix $\frac{1}{2}$ (A + A′) possesses r pairs of roots $\rho_i, -\rho_i$ ($i = 1, \ldots, r$) different from ± 1, there are exactly r c's different from zero. Moreover, these c's are connected with the ρ's by the relation $c_i^2 = 4(\rho_i^2 - 1)$. By changing the signs of the elements in the i^{th} row of S′, the sign of c_i may be changed; and by interchanging the i^{th} and j^{th} rows of S′, c_i and c_j may be interchanged.

Let us denote by V the p by n-p matrix of a's standing in the upper right hand corner of the matrix M or Theorem I. The matrix V is not unique; moreover, the matrix effecting the transfomation of Theorem I is not unique. However, we may make the following statement:

Theorem VIII. If r is the rank of the matrix V, the char. eqn. of the matrix $\frac{1}{2}$ (A + A′) possesses exactly r pairs of roots different from ± 1.

Part II

In the second part of this paper are considered real matrices B which possess the property that $B^2 = -I$. Among the well-known properties of such matrices are the following:

I. There exist no real matrices B of *odd* order such that $B^2 = -I$.

II. If $B^2 = -I$, he char. eqn. of B possesses no roots other than $\pm i$. (Here, $i = \sqrt{-1}$).

III. If $B^2 = -I$, the determinant of B is $+1$.

IV. If B, C are two matrices of the same order such that $B^2 = -I$, $C^2 = -I$, there always exists a non-singular matrix P such that

$$P^{-1}BP = C$$

In part II as in part I we shall consider transformations on these matrices B with regard to the group of all orthogonal matrices. We may then state the following results:

Theorem IX. If $B^2 = -I$, and if ρ is a root of the char. eqn. of the matrix $\frac{1}{2}$ (B + B′), then $-\rho$ is also a root of the same equation.

(Note that in this case we were not required to make the restriction that ρ be different from ± 1 as we were in Theorem II.)

Theorem X. If B is a matrix of order 2n such that $B^2 = -I$, then there exists an orthogonal matrix ψ such that

$$\psi' B \psi = N$$

where N is a matrix of the form:

$$N = \begin{Vmatrix} \rho_1 & \sigma_1 & 0 & 0 & \cdots & 0 & 0 \\ -\sigma_1 & -\rho_1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \rho_2 & \sigma_2 & \cdots & 0 & 0 \\ 0 & 0 & -\sigma_2 & -\rho_2 & \cdots & 0 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & 0 & \cdots & \rho_n & \sigma_n \\ 0 & 0 & 0 & 0 & \cdots & -\sigma_n & -\rho_n \end{Vmatrix}$$

Here $\rho_i^2 = \sigma_i^2 - 1$ $(i = 1 \cdots n)$

Here ρ_i, $-\rho_i$ $(i = 1, \ldots, n)$ are roots of the char. eqn. of the symmetric matrix $\frac{1}{2}(B + B')$ and are therefore all real; moreover, the σ's are connected with the ρ's by the relations:

$$\rho^2 = \sigma^2 - 1$$

Theorem XI. If A, B are two real matrices of the same order 2n possessing the property that $A^2 = -I$, $B^2 = -I$, a necessary and sufficient condition that there exist an orthogonal matrix χ such that

$$\chi' A \chi = B$$

is that the char. eqns. of the two matrices $\frac{1}{2}(A + A')$, $\frac{1}{2}(B + B')$ be the same.

Notes on Osculating Hyperboloids. J. W. LASLEY, JR.

A tangent plane to a surface meets it in a curve with a double point at the point of contact. If the surface is ruled there are usually two points on each generator at which this double point is both a node and a flex point. These points are known as flecnodes, and their locus gives us two flecnode curves on the surface. The tangents to the asymptotic curves through the points of these flecnode curves generate two ruled surfaces known as the first and minus first flecnode transforms of the original surface. It is the purpose of this paper to study the relations between the hyperboloids which osculate the original surface and those which osculate its flecnode transforms.

It turns out that the hyperboloids which osculate the transforms coincide at every generator with that which osculates the original surface, if and only if, the original ruled surface is a quadric. However,

even though the surface is not a quadric, it may at some particular ruling closely resemble a quadric. In that event at that ruling the above mentioned hyperboloids coincide, and the hyperboloid is said to hyperosculate the surface. If the surface is not a quadric, nor at the generator in question resembles one, the meet of the hyperboloid which osculates it with the one which osculates a flecnode transform consists of the generator of the original surface and the corresponding one on the transform each counted twice. Under the same conditions the complete intersection of the hyperboloids which osculate the first and minus first transforms consists of the generator of the original surface counted twice and the additional generators picked out by the tangent planes at the complex points.

Studies on the Nutritive Value of the Peanut: The Effect of Peanut Proteins on Growth of Pigs. J. O. HALVERSON AND EARL HOSTETLER.

Unpublished work has shown that peanut meal contains good proteins for hog feeding when minerals such as calcium and phosphates and green forage are provided. The value of peanut meal for feeding purposes depends on the amount of protein that it contains. This may be lowered due to the presence of an excessive amount of peanut hulls. The hulls have no feeding value. The less hulls, the higher the protein content in the peanut meal.

Poor results from feeding peanut meal to hogs are frequently due to an excessive amount of hulls present in the meal. Such results also may be caused by improper feeding and balancing of the deficiences of the peanuts.

MEMBERSHIP ROLL

May 1, 1925

NAME	DEGREES	ADMITTED TO ACADEMY	INSTITUTION NOW IN	DEPARTMENT	RANK
Alford, A. M.	B.S.	1923	H.S.	S.	T. (1)
Amick, T. C.	Ph.D.	1923	E.	M.	P.
Appleby, J. M.		1925	D.	C.	A.
Arbuckle, H. B.	Ph.D.	1918	D.	C.	P.
Ashe, W. W.	M.S.	1902 (c*)			(2)
Bahnson, F. F.		1918			En.
Barber, Miss Lena	M.S.	1923	M.	B.	P.

* Date of original affiliation, which later lapsed.
c, in date column, charter member.

NAME	DEGREES	ADMITTED TO ACADEMY	INSTITUTION NOW IN	DEPARTMENT	RANK
Barnes, J. T.	A.M.	1921	H.S.		T. (3)
Barrett, H. P.	M.D.	1920			(4)
Barrow, Miss Elva	A.B.	1921			
Bell, J. M.	Ph.D.	1915	U.	C.	P.
Binford, Raymond	Ph.D.	1902*	Gu.		Pr.
Blomquist, H. L.	Ph.D.	1921	T.	B.	P.
Boomhour, J. G.		1905*			(8)
Brimley, H. H.		1902 (c)		Mus.	Curator
Brimley, C. S.		1902 (c)	A.	E.	Ae.
Browne, W. H. Jr.	Cer.EE.	1920	S.	E.E.	P.
Browne, E. T.	M.S.	1923	U.	M.	Pa.
Bruner, S. C.	B.S.	1910		Gvt.	Ento (5)
Bryson, H. J.	A.B.	1923	U.	G.	
Bullitt, J. B.	M.D.	1920	U.	Pa.	P.
Burroughs, R. E.		1924			
Cain, W. K.	LL.D.	1903	U.		Kenan P.Em.
Campbell, Miss Eva	M.A.	1921	Gu.		P.
Campbell, Roy J.	A.B., C.P.H.	1924	S.	B.	Pa.
Canaday, Ernest F.	A.M.	1924	M.	M.	P.
Cobb, Collier	Sc.D.	1902	U.	G.	P.
Cobb, W. B.	A.M.	1914	S.	A.	Pa.
Coker, R. E.	Ph.D.	1906*	U.	Z.	P.
Coker, W. C.	Ph.D.	1902	U.	Bo.	Kenan P.
Coldwell, Miss Inez	A.B.	1923	N.	B.	Pa.
Collett, R. W.		1902			
Couch, J. N.	Ph.D.	1920	U.	Bo.	Pa.
Cunningham, Bert	Ph.D.	1913	T.	B.	P.
Crockford, H. D.	M.S.	1925	U.	C.	I.
Dashiell, J. F.	Ph.D.	1922	U.	Ps.	P.
Daugherty, J. F.	A.B.	1922	U.		I.
Davis, Harry T.	M.A.	1919	Mus.		
Denson, Lee A.		1910*	W.B.	Met.	
Derieux, J. B.	Ph.D.	1920	S.	P.	P.
Dickert, H. A.	A.B.	1925	A.	N.	A.C.
Dixon, A. A.	M.A.	1913*	S.	P.	
Douglas, J. M.	Ph.D.	1924	D.	P.	P.
Eckert, J. E.	M.S.	1922	S.	Z.	Pa.
Eddy, Clifford O.	M.S.	1922	C.C.	E.	As.E.
Edmister, T. H.		1925	U.		
Edwards, C. W.	M.S.	1902	T.	P.	P.
Ellison, W. A. Jr.	A.B.	1924	H.S.	S.	T.
Elmore, K. L.	A.B.	1925	T.	C.	I.

NAME	DEGREES	ADMITTED TO ACADEMY	INSTITUTION NOW IN	DEPARTMENT	RANK
Fant, G. W.	M.S.	1923	S.	P.P.	
Farmer, C. M.	LL.D.	1914		Ex.	
Foster, N. B.		1921*	N.	P.	P.
Frothingham, E. H.	M.S.	1922	F.		Dir.
George, W. C.	Ph.D.	1913	U.	M.	P.
Givler, J. P.	A.M.	1921	N.	B.	P.
Gross, P. M.	Ph.D.	1920	T.	C.	P.
Gudger, E. W.	Ph.D.	1906	A.M.	I.	A.
Haasis, F. W.	M.F.	1922	F.	U.S.F.	As. Silvi.
Hall, Earl H.	M.S.	1924	N.	B.	Pa.
Halverson, J. O.	Ph.D.	1920	A.	C.	
Harvey, James V.	A.B.	1924	U.		Fe.
Hatley, C. C.	Ph.D.	1919*	T.	P.	Pa.
Heck, C. M.	M.A.	1920	S.	P.	P.
Henderson, Archibald.	Ph.D.	1904*	U.	M.	P.
Hickerson, T. F.	A.M.	1915	U.	C.E.	P.
Higgins, C. H.	M.A.	1922	S.C.	S.	P.
Highsmith, J. Henry.	Ph.D.	1923		State Ed.	H.S. Ins.
Hill, M. A.	Ph.D.	1923			
Hobbs, A. W.	Ph.D.	1910	U.	M.	Pa.
Hoffman, S. W.	Dr.	1902			
Holland, Miss Alma.	A.B.	1920	U.	Bo.	
Holmes, J. S.	M.F.	1902*	U.	F.	S.F.
Hook, Alonzo L.	M.A.	1922	E.	P.	P.
Hostetler, Earl H.	B.S.A.	1924	S.	A.	Pa.
Ives, J. D.	M.A.	1910			
Jackson, D. C. Jr.	M.S.	1924	T.	E.	Pa.
Jenkins, S. S.	A.B.	1923	H.S.	P.	T. (6)
Johnson, M. M.	A.B.	1925	M.	C.	Pa.
Jones, E. P.	M.A.	1921		C.	(7)
Jordan, Walter E.	M.A.	1922	S.	C.	Pa.
Kilgore, B. W.		1902*		A.	
Kilpatrick, Martin.	Ph.D.	1924	T.	C.	Pa.
King, Miss Rena.	A.B.	1924	H.S.	S.	T.
Korstian, C. F.	M.F.M.A	1922	F.	F.	
Lake, J. L.	A.M.	1902*	W.	P.	P.
Lalor, Miss M. J.		1925	P.	B.	T.
Lasley, J. W. Jr.	Ph.D.	1921	U.	M.	P.
Lay, G. W. Rev.	DC.C.	1910*			
Lehman, S. G.	Ph.D.	1920	S.Ex.	P.	A.P.
Leiby, R. W.	Ph.D.	1915		A.	En.
Lewis, R. H.	M.D.	1902			
Lineberry, R. A.		1925	U.		G.S.
Lyon, Mary.	B.S.	1914*	G.	B.	P.

NAME	DEGREES	ADMITTED TO ACADEMY	INSTITUTION NOW IN	DEPARTMENT	RANK
Mackie, E. L.	A.M.	1923	U.	M.	Pa.
MacCarthy, Gerald R.	A.M.	1923	U.	G.	I.
McNider, W. D.	M.D.	1912*	U.	M.	Kenan Research
Manning, I. H.		1902*	U.		
Markham, E. C.	A.B.	1924			
Marion, S. J.		1916*			
Martin, A. C.	M.S.	1922	S.	B.	Pa.
Meacham, Frank B.	B.S.	1924	S.	Z & E	I.
Mears, J. S.	B.S.	1924	S.	P.	I.
Mendenhall, Gertrude	B.S.	1910	N.	M.	P.
Meserve, C. F.	LL.D.	1923			
Metcalf, Z. P.	D.Sc.	1910	S.	Z & E	P.
Mitchell, T. B.	B.S.	1921		A.	A.E.
Newlin, R. L.	M.S.	1923	G.C.	M.	P.
Nooe, Sarah	B.S.	1925	H.S.	S.	T. (9)
Nowell, J. W.	Ph.D.	1915	W.	C.	P.
Patterson, A. H.	A.M.	1910	U.	P.	Dean
Patterson, K. B.	A.M.	1922	T.	M.	Pa.
Patterson, P. M.		1925	D.	B.	A.
Pegram, Annie M.	A.M.	1923	G.C.	M.	P.
Pegram, W. H.	LL.D.	1902	T.	C.	P.E.
Penny, J. T.	A.B.	1925	U.	B.	Fe.
Petty, Miss Mary	B.S.	1910*	N.	C.	P.
Plyler, E. K.	Ph.D.	1925	U.	P.	Pa.
Porter, W. L.	M.A.	1922	D.	B.	P.
Poteat, W. L.	LL.D.	1902*	W.	B.	P.
Powell, T. E.		1925	E.C.	S.	P.
Powell, Martha		1925	H.S.	C.	T. (10)
Pratt, J. H.	Ph.D.	1902			Cons. En. (11)
Prouty, W. F.	Ph.D.	1920	U.	G.	P.
Ragsdale, Miss Virginia	Ph.D.	1913*	N.	M.	P.
Randolph, E. E.	Ph.D.	1914	S.	C.	Pa.
Randolph, E. O.	D.Litt.	1916	A.M. Tex.	G.	P.
Rhodes, L. B.	M.S.	1919	A.		A.C.
Rice, F. E.	Ph.D.	1925	S.	C.	P.
Robert, Miss N. L.	M.S.	1925	F.M.	B.	P.
Robison, G. M.	Ph.D.	1924	T.	M.	Pa.
Rodgers, S. E. Jr.	M.A.	1924	S.	P.	I.
Roller, A. F.	M.S.	1921	H.S.	S.	I. (12)
Ruffner, R. H.	B.S.	1921	S.	A.H.	P.
Satterfield, G. H.	A.M.	1920*	S.	C.	Pa.

NAME	DEGREES	ADMITTED TO ACADEMY	INSTITUTION NOW IN	DEPARTMENT	RANK
Saville, Thorndike	M.S.	1919	U.	En.	Pa.
Schallert, P. O	M.D.	1923			
Schaeffer, Florence	M.A.	1923	N.	C.	Pa.
Seiwell, H. R		1925	U.	G.	A.
Shaffer, Miss Blanche	M.A.	1919	N.	H.E.	Dean
Shamburger, Miss Anne		1924	P.	S.	P.
Sherman, Franklin	M.S.	1902 (c)		A.	A.E.
Sherwood, F. W	Ph.D.	1910	A.	C.A.	Pa.
Sherrill, Miss Mary	Ph.D.	1919	H.	C.	PA.
Shore, C. A	M.D.		H.	Pub. H.	
Shunk, Ivan V	A.M.	1920	S.	B.	Pa.
Slay, Ronald J	M.A.	1924	C.	C.	P.
Smithey, S. B	A.B.	1924	U.	M.	I.
Snyder, Laurence H	M.S.	1924	S.	Z.	Pa.
Speas, William E	A.M.	1921	W.	P.	P.
Stiles, C. W	LL.D.	1910		P.H.S.	
Strong, Miss Cora	A.B.	1910*	N.	M.	P.
Stuhlman, Otto Jr	Ph.D.	1921	U.	P.	P.
Summerell, Francis P	B.S.	1924	H.S.	S.	T.
Swartz, Joel H	Ph.D.	1925	U.	G.	Pa.
Taylor, C. C	Ph.D.	1921	S.	A.	P.
Taylor, H. M	M.S.	1920*	U.	C.	I.
Taylor, J. H	A.B.	1922	H.S.		T. (13)
Thies, O. J	M.A.	1921	D.	C.	Pa.
Totten, H. R	Ph.D.	1914	U.	Bo.	PA.
Trice, M. F		1922		S.	P.
Venable, F. P	Ph.D.	1902	U.	C.	P.
Vilbrandt, F. C	Ph.D.	1922	U.	C.	Pa.
Vollmar, Rev. D	A.B.	1925	B.	C.	P.
Wells, B. W	Ph.D.	1920	S.	B.	P.
Wells, B. W. Mrs		1921			
Wheeler, A. S	Ph.D.	1903	U.	C.	P.
Wilkerson, N. F	A.M.	1922	T.	B.	I.
Williams, C. F	M.S.	1922	S.	H.	A.
Williams, J. H		1920	S.		
Williams, L. F	Ph.D.	1910	S.	C.	P.
Williams, V. M	M.S.	1925	S.	A.H.	PA.
Williams, C. B	M.S.	1902*	S.	A.	Dean
Willis, L. G		1924			
Wilson, Henry V	Ph.D.	1902	U.	Z.	Kenan P.
Wilson, John W	B.S.	1925	S.		G.S.
Wilson, R. N	M.S.	1902	T.	C.	P.
Winston, Lulu G	Ph.D.	1921	M.	C.	P.
Wolf, F. A	Ph.D.	1915	A.E.S.	B.	

NAME	DEGREES	ADMITTED TO ACADEMY	INSTITUTION NOW IN	DEPARTMENT	RANK
Wolff, W. A.	A.B.	1923			
Womack, A. W.	A.B.	1923			S.P.
Wood, W. W.	C.E.	1923	D.	M.	P.
Wray, D. L. Jr.		1925			
Wright, Miss E. Katherine	M.A.	1921	N.	C.	PA.
Wright, W. T.	M.S.	1922	N.	P.	P.
Yocum, L. E.	Ph.D.	1922	N.	B.	PA.
Zoeller, Edward V.	P.D.	1923			(16)

Code under Institution

A.M., American Museum of Natural History.
D.C., Davenport College.
Mus., Museum.
W.B., Weather Bureau.
U., University of N. C.
S., State College.
N., N. C. C. W.
T., Duke University.
D., Davidson.
W., Wake Forest.
G., Greensboro College.
Gu., Guilford College.
A., State Department of Agriculture.
Et., Div. of Entomology
P., Peace Institute.
B., Belmont Abbey.
F., Appalachian Forest Experiment Station.
H., State Department Health.
E., Elon.
F.M., Flora McDonald.
M., Meredith.
C., Eastern Carolina.
S.M., St. Mary's.
H.S., High School.

Code under Department

B., Biology.
Bo., Botany.
Z., Zoology.
E., Entomology.
C., Chemistry.
P., Physics.

G., Geology.
Ps., Psychology.
P.P., Plant Pathology.
Pa., Pathology.
A., Agriculture.
N., Nutrition.
M., Medical School.
I., Icthyology.
S., Science.

Code under Rank

P., Prof.
Pa., Assistant Prof.
PA., Assoc. Prof.
S., Secretary National Forest.
C., Civil Engineer.
Pr., President.
T., Teacher.
A., Assistant.
En., Engineer.
I., Instructor.
E., Entomologist.
EA., Assist. Entomologist.
F., Forester.
AI., Assoc. in Icthyology.
Fe., Fellow.
AS., Assoc. Silviculture.
AP., Asst. Pathologist.

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY, OCTOBER 14, 1924, TO MAY 14, 1925

274TH MEETING—OCTOBER 14, 1924

COLLIER COBB—*The Deflective Effect of the Earth's Rotation as Shown in the Loess Plain of China.*

OTTO STUHLMAN, JR.—*The Atom. What is it?* (Presidential Address.)

ELECTION OF MEMBERS

The following members of the faculty were elected to active membership in the Society: Dr. E. W. Atkins, Mr. C. H. Benson, Mr. J. N. Coffey, Mr. C. R. Harris, Mr. S. T. Helms, Mr. V. A. Hoyle, Mr. E. D. Jennings, Dr. E. K. Plyler. The following students were elected to associate membership: from the Department of *Botany*—E. B. Shaw, H. T. Thompson; *Chemistry*—F. L. Brinkley, R. M. Byrd, B. G. Carson, S. C. Collins, Miss L. F. P. Cutlar, E. B. Dalton, W. M. Mebane, V. B. Rollins, C. D. Schiffman, R. R. Sugg, T. T. Walker; *Civil Engineering*—G. A. Ausband, C. G. Barton, Jr., F. M. Bell, W. A. W. Cramer, R. P. Farrell, M. M. Grier, M. F. Hetherington, H. A. Lawrence, M. B. Logie, F. D. Owen, R. J. Rosenberger; *Electrical Engineering*—B. C. Cooper, H. A. Davis, Keith Grady, J. W. P. Hodges, R. H. Jackson, C. L. Jones, G. E. Justus, J. B. London, J. R. Purser, C. E. Ray, S. S. Richards, O. R. Rowe, P. M. Rutherford, T. B. Smiley, I. B. Stout, F. Waldhurst; *Geology*—H. R. Seiwell, J. H. Watkins; *Hydraulic and Sanitary Engineering*—J. H. Albergotti, H. Cantey, H. M. Holmes, J. B. Padgett; *Mathematics*—J. R. Abernethy, L. L. Garner; *Medicine*—E. D. Apple, E. S. Avery, H. H. Bass, J. N. Bethea, F. H. Corpening, H. N. Couch, E. M. Fetter, J. W. Foster, G. V. Gooding, F. M. Hauser, J. B. Hunter, W. C. Hunter, J. A. Jones, Jack Lazarus, R. Z. Linney, Z. F. Long, E. M. McDaniel, A. M. McDonald, R. H. McDowell, N. W. Mackie, B. L. Malpass, Miss Martha Michal, J. W. R. Norton, H. W. Primakoff, Miss Sallie Rutledge, C. N. Stenwall, L. W. Temple, Jr., L. P. Corbett, N. V. Jackson, A. K. Maness, V. R. Sink, J. H. Wall; *Pharmacy*—H. Amin, O. D. Biddy, W. W. Blades, Miss Lillian Burch, L. Gilreath, L. S. Miller, E. H. Tate, H. M. Winders; *Physics*—E. A. Farrel, W. D. Harrel, R. M. Smith; *Psychology*—J. C. P. Fearington, W. M. Linker, R. S. Matthews, S. F. Pakula.

276TH MEETING—DECEMBER 9, 1924

E. W. ATKINS—*The Efficiency of the Eye Under Different Intensities of Illumination.*[1]

Subjects worked at a rather routine task under five different intensities of illumination. The rate and constancy of the work was taken as a measure of the work done under the differing illuminations. The condition of the subjects was determined by pulse records and by coordination tests before and after the work. The same type of work, series of condition tests, and brightness of test object was later employed with a substitution of white surroundings (coefficient of reflection 90%) for the black surroundings (coefficient of reflection 4%) of the first condition.

It was found with black surroundings that the optimum brightness of the test object was about 37 millilamberts. It is interesting that this brightness closely approximates the maximum brightness of a surface reflecting sunlight. This brightness was shown to be far too great in case the surroundings as well as the test object were light instead of dark.

W. C. COKER—*The Puff-Balls and Their Relatives.*

Mr. J. V. Sykes, of the Department of Zoology, was elected an associate member of the Society.

275TH MEETING—NOVEMBER 11, 1924

J. M. BELL—*Electrometric Methods of Chemical Analysis.*

A brief outline was given of the theory of electrometric titrations, involving the detection of end-points by voltage readings between electrodes in the titration mixture. The advantages and disadvantages of the method were reviewed.

D. A. MACPHERSON—*The Relation of Hydrogen Ions to Bacteria and Public Health.*

277TH MEETING—JANUARY 13, 1925

W. C. GEORGE (with Dr. W. E. Hoy, Jr., of the Presbyterian College of South Carolina)—*Somatic Chromosomes of the Opossum.*

Material used consisted of young opossums about 50 mm. in length.

[1] This investigation was carried on in the laboratories of the Johns Hopkins University.

Counts have been made and figures of metaphase plates obtained from several organs of three individuals, one male and two females. The number of chromosomes in somatic cells is 22 for both sexes. The male has the x-y combination of sex chromosomes and the female has the x-x combination. No evidence of fragmentation of chromosomes has been found.

ARCHIBALD HENDERSON—*Relativity and Atomic Structure.* (This paper appears in full in this issue).

COLLIER COBB—*Brief Notice on a Combustible Clay from Ontario, Canada.*

The following students from the Department of Zoology were elected associate members of the Society: J. M. Brewer, R. H. Wright, Jr.

The Society directed the Recording Secretary to send a letter of congratulation to the Adriatic Society of Natural Sciences in honor of their fiftieth anniversary and to express the Society's regret at its inability to send a representative to Trieste for the celebration of the anniversary.

278TH MEETING—FEBRUARY 10, 1925

WILLIAM CAIN—*Maxwell's Theorems of Relative Displacements.*

The three well known theorems entitled, "Maxwell's Theorems of Relative Displacements," were proved, for supported beams, by Clerk Maxwell by the "method of work." The case for the cantilever, or beam or arch-rib fixed (*encastrée*) at one end, free at the other, is simpler; and Maxwell's three theorems have been proved by the writer in an original manner, by aid of certain theorems of elasticity, for such cantilevers. The solution does not involve "the method of work" and is simpler than Maxwell's solution and entirely distinct from it.

In the solution of the usual arch-rib without hinges, the three theorems for the cantilever are utilized in finding the reactions and consequent stresses anywhere in the arch, so that it seemed that an independent proof of Maxwell's Theorems for the cantilever for the load having any direction would be welcome.

E. K. PLYLER—*The Infra-Red Absorption of Ice.*

The absorption of ice is dependent upon the direction of the plane of polarization for the near infra-red region. Crystals were cut with the

optic axis parallel to the surface. Plane polarized radiation was allowed to fall upon the crystal and the per cent transmission determined. The crystal was set in three positions: first, so that the transmitted radiation constituted the ordinary ray, second, so that the transmitted radiation constituted the extraordinary ray, third, so that the incident energy was about equally divided into two rays. For the first position, with a thickness of 5 mm., absorption bands were observed at the following wave-lengths with the corresponding per cent transmission: 0.81μ—55%, 0.92μ—54%, 1.06μ—46%, 1.29μ—27%. For the second position the values were: 0.79μ—93%, 0.89μ—94%, 1.02μ—93%, 1.26μ—57%. For the third position the transmission curve fell between that of the first and second positions and showed both sets of bands. The region from 1.4μ to 1.7μ was studied by using a specimen 1 mm. thick. The position of maximum absorption was located at 1.5μ. The incident energy was unpolarized.

279TH MEETING—MARCH 10, 1925

T. F. HICKERSON—*Vertical Curves of Greater Flexibility for Highways and Railroads.*

Vertical curves are necessary for roads and railroads where there is an abrupt change in the gradient whether it be in and out of a ravine or over a hill. The parabola whose offsets vary as the square of the distance has been universally used for these curves. It gives a rather pleasing vertical profile and has the advantage of simplicity. For grades as flat as those usually occurring in practice, the ordinary parabola really coincides almost exactly with a circular arc.

Although the parabolic or circular arcs are satisfactory curves for most cases, yet they do not afford the flexibility which is often desirable, especially in the case of railroad and highway grade crossing eliminations,where in a limited distance the offsets should vary *faster* or *slower* than the square of the distance.

The curve adaptable to any case of vertical alignment is a parabola whose general equation is

$$y = \left(\frac{x}{l}\right)^n E \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The equation of the ordinary parabola is

$$y = \left(\frac{x}{l}\right)^2 e \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where l = total length of parabolic curve; E or e = central offset from tangent to curve.

If both curves have the same origin and parallel tangents at the central points (where $x = l$), then equating the first derivative of equations (1) and (2) we have

$$\frac{dy}{dx} = n\left(\frac{l}{l}\right)^{n-1}\left(\frac{1}{l}\right)E = 2\left(\frac{l}{l}\right)\left(\frac{1}{l}\right)e; \therefore n = \frac{2e}{E} \quad \ldots\ldots\ldots\ldots (3)$$

By giving E various values ranging from 0.5e to 1.5e and differing by 0.1e a set of parabolic curves are obtained which have central offsets more or less (as the case may require) than that of the usual parabola. Thus, if it is desired to have a central offset = 1.2e, a parabola whose equation is

$$y = \left(\frac{x}{l}\right)^{1.67}$$

is suitable.

Tables have been compiled by the writer giving offsets to all points of any curve whose equation is $y = \left(\frac{x}{l}\right)$ for values of n ranging from 1.33 to 4.0. Thus, if a + 6 per cent grade meets a −4 per cent grade at a point where space is available for a vertical curve 400 feet long (200 feet on either side of the point of intersection);

$$l = 200 \text{ feet},$$

$$e = \frac{200}{4}\left(\frac{6 - (-4)}{100}\right)$$

= 5.0 feet = central offset for ordinary parabola.

Now if it is desirable to make the elevation of grade at the center of the curve 2 feet lower than that given by the ordinary method; for obtaining a more extensive unobstructed view over a hill or for allowing greater head room under a railroad; then with $n = 2 \times \frac{5}{7} = 1.43$ (formula (3)) it is only necessary to refer to the proper table for offsets defining the appropriate curve.

A. H. PATTERSON—*Structure of the Atomic Nucleus.*

A brief account was given of the methods of attack on the problems connected with the nucleus; its size, density, shape, constitution, etc., especially the method used by de Broglie, Meituer, Ellis and others in evaluating the quanta of the high-powered gamma rays from radioactive products.

The new theory of energy levels within the nucleus was outlined, with the evidence in favor of it.

280TH MEETING—APRIL 21, 1925

R. E. COKER—*Some Observations on Protozoa.*

Formation of shell by Peranema. In a "wild" culture there were observed: (1) many minute colorless protoplasmic bodies (12–23μ) of irregular and variable forms and offering no features of recognition other than occasional traces of an eyespot and form-changes suggestive of a euglenoid relationship; (2) numerous symmetrical dark-colored ovoid shells (24–27μ), finely sculptured with spiral beaded lines. After protracted observation, one of the colorless bodies was observed to assume the form of a Peranema, with active flagellum and bright eyespot. Figures were given to show how this elongate and distinctly asymmetrical Peranema converted itself quickly into first a heart-shaped, then an ovoid form of perfect symmetry, and immediately surrounded itself with a fairly thick spirally beaded shell. Flagellum and eyespot were retained for a time, and a large vacuole was in evidence. The shell was at first perfectly clear but gradually darkened.

Choanoflagellates of the genus Codosiga. These minute collared protozoans were attached, with usually 2 or 4 individuals to a stalk. While the slender rigid stalk admitted of incessant mechanical vibrations, observation of a colony during a period of about 2 hours revealed no change of form or of relative position of an individual, no shifting of position of vacuoles or of light-refracting bodies, no external movements other than a continual waving of very delicate flagellum. In contrast, and suggestive of a high rate of metabolism, were the frequent contractions of 2 relatively large vacuoles, symmetrically placed, strictly alternate in action, and with a periodicity of one contraction in about 9 seconds.

There were illustrated the changes in appearance of a small Ameba that when first noted displayed a typical *radiosa* form. Apparent fusion of pseudopodia occurred to form a broad and extremely thin ectoplasmic sheet of fluctuating outline. Throughout a long period of observation the body of granular cytoplasm showed no notable changes of size or form; meantime the outline of the ectoplasmic sheet changed so incessantly and rapidly, with such a flame-like action, as to suggest that the particular character of its movements were the result of the play of molecular forces between ectoplasm and environment, rather than

that they were merely incidental to the assumption of a locomotive or trophic form.

Observations on *Ameba proteus* were reported in close harmony with Mast's recent illuminating account of locomotion in Ameba. An inner core of liquid cytoplasm flows in the direction of movement of Ameba, being surrounded above, below and on the sides by a semi-solid motionless layer, which is constantly liquifying and falling into the stream posteriorly, while the streaming protoplasm solidifies marginally in the advancing pseudopodium without backward flow other than a slight "settling" of granules (a backward movement of 5μ, at most, in an Ameba 300μ in length. The outermost layer (plasmolemma), though separated from the streaming inner cytoplasm by a motionless layer, advances, as observed, at a somewhat slower rate than the inner stream, but with a force sufficient, not only to cause currents in the water, but to dislodge external objects offering evident resistence. In consideration of locomotion in Ameba, emphasis is frequently laid upon the "streaming of the endoplasm," but perhaps emphasis should rather be laid upon the movement of the plasmolemma, with which locomotion seems to begin. It is suggestive, at least, to think of the actively moving outer layer as possibly a distinctive organ of locomotion, as much so as the cilia or the flagella of other kinds of protozoa; then to inquire to what extent the conspicuous flow of granular plasmosol is a secondary but essential feature of the coördinated activity of the organism in locomotion.

E. V. KYSER (with C. R. Whitehead and H. Amin)—*The Inhibitory Action of Antiseptics on the Activity of Pepsin.*

A study was made of the effect of various antiseptics on the peptolytic action of pepsin when added in the amounts usually given as an average oral dose. The classification of the antiseptics and the antiseptics used are those classified by Potter[2] as follows: Strong Antiseptics; Corrosive Sublimate; Formaldehyde; Hydrogen Peroxide; Silver Nitrate; Gold Chloride; Zinc Chloride; Copper Sulfate; Iodine; Potassium Permanganate; Carbolic Acid; Creosote; Chloroform; Thymol; Menthol; Alum; Tannin; Acetanilid; Antipyrin.—Moderate Antiseptics; Boric Acid; Chloral Hydrate; Ferrous Sulfate; Zinc Sulfate; Arsenic; Quinine; Salicin; Sodium Salicylate; Salol; Mercuric Iodide; Eucalyptol; Sulphurous Acid; Zinc Sulfocarbolate; Bismuth Subgallate;

[2] Handbook of Materia Medica, Pharmacy and Therapeutics.

Resorcinol.—Feeble Antiseptics; Benzoic Acid; Sodium Borate; Sodium Bicarbonate; Calcium Chloride; Sodium Chloride; Barium Chloride; Strontium Chloride; Ammonium Chloride; Ammonium Sulfate; Alcohol; Sodium Hyposulfite; Potassium Chlorate; Potassium Iodide; Glycerin.

The method followed was that of the U. S. P. IX for determining the peptolytic value of pepsin. The antiseptics were added directly to the egg albumen and two control samples, one with pepsin and without antiseptic, the other with antiseptic and without pepsin were run with each determination. The results obtained were tabulated to show the gms. and per cent. of pepsin and antiseptic, the per cent. of the unchanged albumen and the per cent. of inhibitory action.

281ST MEETING—MAY 14, 1925

J. W. LASLEY—*Some Hyperboloids of the Flecnode Suite.*

W. F. PROUTY—*Relation of Rock Character and Structure to Topography in the Central Belt of the Folded Appalachians.* (Illustrated.)

The area studied lies between the Alleghany Front in West Virginia and the eastern boundary of Hardy County, West Virginia, along the Virginia border. It is roughly about 30 miles square. In it are exposed the sandstones, shales and limestones ranging in age from the middle Ordovician to the Mississippian. These have an aggregate thickness of about 14,000 feet.

In this section there are three horizons of sediment which are very resistant to erosion and which constitute relatively competent portions. These are the Medina sandstones near the bottom of the geological column, the Oriskany sandstone near the middle of the column and the Pocono sandstone near the top of the column. All the higher elevations in the area studied are held up by one or another of these three resistant horizons. The long and narrow ridges are usually the outcropping edges of these layers. The broad topped and steep sided elevations are usually synclinal mountains and the rather regular dome-shaped or canoe-shaped mountains are anticlines, whose surface rock is sandstone which has not as yet been pierced by the agents of erosion.

The eastern portion of the area studied has beautifully developed anticlinal valleys, similar to the ones so common in the southern Appalachians where erosion has passed by the heavy sandstone beds in its

downcutting, and is now wearing its valleys in the Ordovician and Cambrian shales and limestones. Just west of the Virginia border are three deeply eroded anticlinial valleys in the Ordovician shales. These are surrounded by the mountains formed from the steeply inclined Medina sandstones.

In the central portion of the area the chief heights of land are sustained by the Pocono sandstone in the centre of synclinal folds.

Toward the western portion of the area, where the erosion has removed the higher group of sandstones and where erosion has not as yet cut through the lower sandstone group, we have the most varied conditions. In the Moorefield Valley and the area immediately to the west, there are many fine examples of perfect anticlinal hills. These occur best where the Oriskany sandstone arches lose their Marcellus black shale covers by erosion. In these arches, as erosion continues, the Oriskany sandstone in the central portion of the arch is worn through and the underlying shales quickly develop into valleys. As these valleys continue to grow deeper, erosion is finally checked by the very resistant Medina sandstones. These sandstones gradually rise to form a mountain as the easily eroded shales and limestones about it are eaten away by the greater erosion on their outcrop. We have thus the changing conditions in the same structure from an anticlinal hill to an anticlinal valley and back again to an anticlinal hill, and with the piercing of this bottom sandstone a return to the anticlinal valley.

I have never seen a locality in the Appalachian Region in which topography so minutely reflects the structure and rock character as it does in the area about Moorefield. Elkhorn Mountain Anticline emerges from the valley level in the Oriskany sandstone arch, which rises gradually toward the southwest. This sandstone forms the crest of the gradually rising mountain. At a point about four miles south of of the northern terminus, the sandstone arch is completely eroded from the centre of the arch. If the axis of the anticline is followed toward the southwest, it will be seen that the elevation drops off rapidly in the limestone and shale formations underlying the Oriskany, until, at a point about two and a half miles beyond the Oriskany outcrop, the erosion has eaten completely through the soft formations, and the Medina sandstone is brought up by the increasing elevation of the arch. The surface rises from here to the southwest until the crest of the arch is reached. From this point on to the southwest the topography is repeated in reverse order to that in the northeast half of the anticline.

In a panoramic picture of Patterson Creek Mountain Anticline one

can identify the structure from the topography. This mountain has been less deeply eroded than Elkhorn Mountain, but structurally it is much more complex. There are several minor cross folds in the anticline with corresponding areas of greater axial elevation. In each of these latter areas of greater axial elevation erosion has succeeded in piercing the Oriskany sandstone and has eroded deeply into the underlying limestones and shales, thus giving a depression in the mountain corresponding to the arching of the strata. In a similar way in the minor cross synclines or low places in the structure, erosion has not yet pierced the sandstone and as a result such positions are highly elevated.

In geological mapping much time and labor in field work can be saved by a careful study of the relationship between the topography rock character and structure and erosion.

ELECTION OF OFFICERS

The following officers were elected for the year 1925–1926: President—H. R. Totten: Vice-President—Thorndike Saville: Permanent Secretary—J. M. Bell: Recording Secretary and Treasurer—E. T. Browne: Publications Committee—W. C. Coker, Collier Cobb, and J. M. Bell.

THE LIFE AND HABITS OF THE HONEY BEE[1]

By H. B. Arbuckle

The suggestive and mellifluous scientific name of the tiny creature that shall engage our attention this evening is *Apis mellifica*, an appropriate appellation for an address before the Academy of Science.

It belongs to the Order, Hymenoptera, which includes the most interesting of our insects, such as ants and bees.

There are many species of bees. The *dorsata* is a large bee that hangs its comb on the limb of a tree. *Florea* is a very small bee that has not learned that hexagonal cells are the most economical. Among the honey gathering bees are the *unicolor* of Madagascar, which produces a very thick syrupy honey, and the *trigona* and *melipona* of Mexico and Brazil that commend themselves to some because they have no sting. Our boyhood experiences are inseparably connected with bees that bear the common names of mud-dauber, wasp, hornet, yellow jacket and bumble bee and not many of us have grown up without the indelible impression of one or more of these familiar enemies of our earlier years.

The species *mellifica* includes over 4000 varieties. Those best known to us are the *ligustica*, the Italian bee, noted for its docility, prolificacy, honey gathering qualities, ability to work blossoms that others cannot work, noted for their eager defence of the hive; the Cyprians, irritable, breeding late in the fall; Syrians, noted for the large number of queens produced in the hives, often over 100; the Holy Land bees famous for choosing the carcass of a lion for their home; the Carniolans; the Caucasian, pronounced by Hoffman as superior even to the Italian.

If we should survey the whole range of bee life, the tiny *prosopis* that lives in miserable solitude and poverty of both food and young must be at the bottom, while our splendid *Apis mellifica* has scaled the heights of instinct and ingenuity.

When my story is ended, I trust you will be ready to place *Apis mellifica* on the highest pinnacle of insect life.

[1] The Presidential Address before The North Carolina Academy of Science, May 1, 1925.

INMATES OF THE HIVE

Let us take a walk through the apiary and make what may be for many of us new friends. As we pause by a populous colony, we are first impressed by the musical hum that seems to emanate from this busy factory at our side and fill the air on every side, for it is near midday and in the height of the honey season. We next catch sight of moving objects that are either seen for a moment to vanish almost with the speed of bullets into the depths of the azure sky beyond us, or coming with unerring aim to the alighting board at our feet. Some may be falling short in the grass before the hive as if exhausted under their heavy loads and with energy spent fail to reach their goal. We watch them quickly recover strength and crawl forward in desperate haste to their beloved portal. We stoop forward and observe a double row of bees at the entrance with vibrating wings that the eye can catch with difficulty. These are the electric fans that ventilate the hive and make it possible for the stupendous labors to continue in the crowded factory. We may perchance see many others marching in line just inside the entrance and we notice some of those that are leaving the hive tumbling over this line of bees in their haste to get back to the fields, but we are more interested in the challenge given to those coming in. The wave of antennae, the password received, "all is well." The sentinels thus make sure that those who enter are friends. How these faithful guards identify at once every one of the 100,000 inhabitants of the hive will remain one of the mysteries of the apiary. Those who claim that it is by smell must ascribe to them an acuteness of olfactory skill that transcends all animal gifts.

So interested have you become in this glimpse of bee life that I am not surprised that you ask to see the inside workings of this factory. After two or three puffs of smoke from my smoker and a few gentle taps on the hive, I cautiously pry up the corner of the super and blow some smoke across the top of the frames. I then lift off the freighted super. It is fortunate indeed that smoke has such a remarkable influence on the inmates of the hive. The moment before this smoke was blown in a number of sentinels were moving along the top of every frame in the hive, guarding well the entrance to the storehouse above. These instantly forsake their posts. Is it from fear? I cannot believe it, for have I not seen guard bees sacrifice their lives with eagerness for their home? Have I not seen them follow some monstrous enemy for long distances from the hive to reek a savage vengeance on him who

dared to invade the precincts of their home? I would rather believe that this smoke portends for them some dreadful disaster and the time has come to prepare for what lies before. They must save as much as possible of the previous stores, so with few exceptions the wretched, hopeless dwellers in this threatened home plunge their heads into the sweets of open cells and even cut the caps away from sealed cells and gorge themselves with the food they have stored away. Once filled with honey, they seem disinclined to fight or sting. Some may say that full stomachs have greatly improved their disposition. At any rate, if my movements are slow and I am careful not to jar the frames, (bees do abhor a jar) I can lift out the frames without the least show of anger on the part of the bees. Are you looking now? The frame lifted out is thickly covered with bees. Chiefly they are of similar size and coloring as peas from the same pod. These are the worker bees which are neuters, or rather undeveloped females. But what luck! Here near the center of the frame is a bee very different. The shape is more that of a wasp, yet more graceful, the color is brighter, the wings longer, the head smaller, and if we could examine this head with a magnifying glass we would find there are about 4000 eyes, while the workers have 8000. See the circle of the workers about this beautiful bee with their heads all turned toward it, and they are stroking it with their antennae and seem to be waiting on every move. We see this stately bee insert her head into a cell and after careful examination the head is withdrawn and the abdomen inserted. As the cluster moves away, we note a pearly egg in the cell. This is the queen, the mother of the colony. Her business is to lay eggs. As evidence that she attends to it well, I cite the fact that she often lays 3000 eggs in one day. As she slowly moves forward, laying eggs in each empty cell according to a very definite plan for every frame, we find no evidence of her issuing orders or assuming any control, yet the workers seem to watch her every move, show her great respect and strive in every way possible to make her work easy.

There is a third inmate of this hive. This is a large fly-shaped bee, the male or drone. He is clumsy in his movements, boisterous, careless, will even foul the beautiful combs with his droppings. When he takes wing he makes a big noise. Watch him all you may, you find him doing nothing but running about and eating.

We shake the bees from one of the frames and view the exquisite handiwork of the workers. We are in the brood chamber of the hive. We see that each frame is composed of a double set of hexagonal cells.

almost perpendicular to the plane of the frame and placed bottom to bottom. Examining an empty cell, we find the bottom is made up of three triangular pieces that meet at a central point. A noted mathematician was once asked to figure out the shape of a cell that would most completely utilize space for its contents and require least wax. The form given was almost precisely that found in the bee hive. The cells all appear to be indentical in size except a few cells along the edges of the frame or in the corners. This set of cells are also alike in shape but distinctly larger. These are drone cells.

The middle of the frame has most of the cells capped, and as we look we see a cap cut through and there emerges a young worker bee. The queen had laid an egg in this cell just 21 days before, and now a new worker is added to the force. Scattered through these cells occupied by eggs and young bees in various stages of development are cells containing honey and cells filled with a red or yellow powder, which is pollen. Thus the food used for rearing the young is conveniently placed for the nurses that feed the babies.

Around the capped brood cells in a circle are cells containing large worm-like larvae. In ever widening circles, the size of larvae diminish until they appear as tiniest worms. Still further out is a circle of cells containing eggs. Thus does a good queen arrange her brood. Around about this array of the young are cells filled with honey, some capped, some uncapped, and many cells filled with pollen. As we reach the edge of the frame, we see a drone emerge from one of the large cells and we soon observe that every large cell supplies a drone and every small cell a worker, and this raises the question: can the queen determine sex!

Determining Sex

The queen is a perfect female in the sense that the female sex organs are perfectly developed, but she is more than this. She might be called an hermaphrodite. The bees in common with certain other insects possess the power of parthenogenesis, that is, their unfertilized eggs will develop. If a queen is never fertilized, her eggs will develop, but they will always produce males. Now the queen is not the only female of the hive and is not the only bee that can lay eggs. The worker bees may acquire the power of producing eggs and often do when a colony is kept queenless for three or four weeks. These laying workers may lay eggs in abundance, often three and four in one cell, but their eggs when developed produce only miniature drones. So they too have the power

of parthenogenesis. The queen, however, when properly mated can lay eggs that will produce female bees and it has been proved by Quinby, Langstroth and others that only fertilized eggs can produce females and can produce only females. The queen possesses an interesting organ called the spermatheca, which on mating is filled with spermatozoa or male germ cells. These remain alive and active during the entire life of the queen, which may cover a period of five years. Some scientists, such as Cook and Dzierzon, believe that the queen has perfect control over this spermatheca, so that at will she can lay unfertilized or fertilized eggs. This gives her complete control over the sex of her offspring. They claim that drones have been produced in worker cells.

Other students of bee life, as Quinby, Langstroth and Root, believe that the determination of sex is rather mechanical and it is thus almost as much in control of the worker bees as of the queen. From my own observations, I am compelled to agree with the latter group. We believe that the size of the cell in which the egg is laid determines whether it is fertilized or unfertilized. The larger cells will receive an egg from the laying queen without producing any pressure on the abdomen, hence the eggs in these cells are all unfertilized and will produce males. I have never seen a worker bee develop in the larger cells. On the other hand, when the queen inserts her abdomen in a worker cell, the pressure causes the spermatheca to eject a male germ and the egg of a normal queen is always fertilized and the offspring is female.

I should like to cite an observation of mine, which has been hitherto unpublished. A few years ago I discovered many drone bees in worker cells in a certain hive. At first I thought I had a case of laying workers, but was surprised to find the distribution of the brood similar to that of a normal queen. Laying workers distribute their eggs at random through the cells. Then I observed quite a number of normal workers issuing from worker cells. It was indeed a puzzle. After diligent search for a queen, I found a dwarf bee with all the markings of a queen. She was so small that she passed readily through the bars of a queen guard. She may have been a virgin, but another fertilized queen would have to be present to explain the female offspring. To test the matter I removed this queen for five days and not an egg was deposited in the hive, and queen cells were started. This was proof that she was the only queen in the hive. My explanation is this: when she inserted her small abdomen into a worker cell, the cell did not always bring sufficient pressure to cause the ejection of a male cell, so the egg devel-

oped into a male. I may cite another instance of a hive which I had supplied with frames with complete worker combs in which I never found a male bee.

THE MAKING OF QUEENS

Before closing the hive we may have the good fortune to find a group of large cells that are circular. On closer examination, we may find an egg in one and in another a drop of white cream-like substance with a tiny larva imbedded in it while a third may be drawn out into a corrugated cone an inch in length and securely capped. We have before us the stages in the making of queens. These are queen cells and although they are even larger than drone cells, the eggs found in them are always fertilized. The eggs are identical with the eggs found in the worker cells. Some beekeepers use this argument to show that the queen has control of the fertilization of her egg, but may not the queen by curving her abdomen to deposit the egg in this cell of peculiar form secure the pressure required to cause fertilization, or is it not possible that these eggs have been placed in the cells at the proper time by the worker bees? Two years ago, I almost secured proof that worker bees actually carried fertilized eggs from adjoining hives in an attempt to secure a queen. I had removed the queen from a colony infected with European foul brood. This colony had been queenless for 24 days and every young bee that had not been killed by the foul brood had been developed. There had not been an egg in this hive for three weeks. There was no evidence of laying workers. A worker's egg could only produce a drone. On opening the hive on the 24th day to introduce a new queen, I was surprised to find three capped queen cells. Whence came the eggs that produced these queens? Knowing that the first queen that emerged would destroy the other two, I removed two of them to nuclei. One of these proved to be dead from foul brood. The other died from chilling. The cell left in the hive reached maturity and a very nice virgin queen emerged. I valued her highly, but thought it best to introduce her into another hive. By some mischance she was destroyed, although I employed a method that has given almost universal success. If worker bees did not carry these eggs, I am without explanation of this interesting phenomenon.

There remains a most interesting fact about this making of queens. If worker eggs, that is, fertilized eggs identical with those found in worker cells, produce queens, what is the method employed to cause this profound change in development? It is believed to be the result

of a specially prepared food that has defied the skill of the chemist. The cream-like substance of aromatic odor and rich taste found in the queen cells is known as Royal Jelly and is specially prepared by astute worker bees for this one purpose. What profound changes are produced in this tiny female larva by this food which is always so generously supplied to all swarm queen cells! In fact, it is wastefully supplied, for the queen larva is rarely able to consume more than half of it. What a suggestion this offers to us! Why could we not discover some rich combination of nutrients that would cause our children to grow forth into a beauty and perfection, which we at present have never produced. Our sweet little girls might be developed into queens of matchless perfection. The chemists have brought vitamins to their aid, but I think the bees are still in the lead. What a rich store of vitamins must be found in this royal jelly!

But there is one phase of queen making that places it at the apex of achievement. In case a colony is deprived of its queen, the workers may for a few days go into a slump, the field bees forsake their work, and the fine spirit of the hive seem broken. The workers become sullen and irritable and all work but the feeding of the babies is neglected. If there be a worker egg in the hive, the workers in two or three days proceed to develop a queen from their own resources. They will cut the inner walls from four adjacent worker cells that contain larvae about three days old. They will destroy all the larvae but one and supply this one with royal jelly. The cell is then drawn out into a typical cell and on the tenth day a queen will emerge.

We now carefully return the frame to the hive and close it up. Finding those queen cells has informed me that this hive will swarm in three days, weather permitting, and we cannot miss that great event.

THE PLAY OF THE CHILDREN

As we leave the apiary, we see another beautiful sight. The muscial hum about a hive near at hand is rapidly rising to a crescendo. A large number of bees are pouring from the entrance and passing in hilarious, riotous movements far up into the air, their wings producing these pleasing sounds that are arresting our attention. These merry bees are literally dancing in the sunshine, and enjoying perchance for the first time the exhilarating sensation of a flight in the open air. It is the play of the children, and quite unlike the behaviour of the swarm, for which it is often mistaken. In five minutes the play spell is over and the young workers are rushing back to their tasks in the hive.

THE DIVISION OF LABOR

One of the most interesting features of a colony of bees is the perfect system that characterizes all of their work. The basis of this system seems to be a division of labor among all the 80,000 workers. This has received the attention of all bee keepers, but even such close students as McCook and Langstroth, have never been able to give very accurate statements concerning it. How the bees are selected for the various duties remains the sublime mystery of the bee colony. None of us believes that any one bee is assigned to one task for her entire lifetime, which in summer rarely exceeds 90 days, yet the high efficiency of all the work about the hive could be best explained by this. All of us who are interested in bees have learned some interesting facts by marking bees. Maeterlinck has carried out many experiments that gave unexpected results. I have by marking certain comb builders in the super become convinced that in a period of two weeks none of these leave the hive. I have also learned that certain bees that have been assigned to sentinel duty seem to stay on this task several days at a time. There are many assignments. There are field bees, comb builders, wax makers, nurses, guards, ventilators, undertakers, cleaners, etc. The young workers are generally assigned to nursing, but I am reluctant to believe that the care of queen cells is ever entrusted to them. The older bees are generally found among the foragers, and they show many evidences of their hard service in torn wings, broken legs, slick bodies. It is quite interesting to watch the undertakers. The hive is kept scrupulously clean and dead or injured bees are not permitted to remain long in the hive. We are convinced of the great strength of the honey bee when we see it drag the dead body of one of its fellows to the entrance and then seizing it in its legs rise in flight and pass rapidly away from the hive.

THE SPIRIT OF THE HIVE

It was once believed that the queen was the sole sovereign of the hive and as such directed all of its activities. True, the queen determines most of the habits and qualities of the hive, as she is the mother of all the bees and they must inherit her qualities, but I have found no evidence that she has any control over the activities of the hive. On the contrary, she seems to accept the orders of the hive. The love and respect of the worker bees for the queen seem based on an instinct that tells them she is essential to their life and development. Let her fail in her duties as producer of life and they will supersede her; they

will rear another queen and ruthlessly kill the one that has failed them and it is almost pathetic to think that they may order her to lay an egg in a queen cell that will produce a queen that will usurp her place.

The queen does not decide that a swarm is necessary, nor does she lead forth the swarm as some say. I have seen a swarm issue twice from the hive before the queen will follow it. The government of the hives seems to be in the hands of these maidens that have accepted lives of labors and self-sacrifice for the sake of their community, for the sake of the welfare of the race. Each doing faithfully her duty, as it is presented, is sure to find conditions that interfere, and this spirit or feeling seems to spread through the hive until with one accord all are ready to carry out the plan that makes for the welfare of the whole. Wonderful force, sentiment, spirit that guides unerringly every individual! No one has ever discovered a coward, an idler, a traitor in a bee colony.

THE SWARM

The finding of those queen cells proved that the spirit of the hive had decreed the most momentous, the most inexplicable procedure that can be found anywhere in the annals of animal life. It has set the hour for the great annual sacrifice, for almost to the day on the 10th day, after the capping of the first queen cell, the swarm will leave its wonderful home, built up with personal sacrifice that no words can express. Just when a whole people have perfected their domestic plans, when they have obtained the topmost pinnacle of prosperity and power, suddenly and seemingly without a regret decide to abandon to the generation to come their wealth, their home, all the fruits of their labors. They do this, when they know they must face the perils and hardships of a cold and relentless world. The step often means ruin and always poverty and struggle. At the prescribed hour, approximately 70,000 of the 80,000 inhabitants of this beautiful city will say farewell forever to all they hold dear. They leave only when they have attained the apogee of prosperity. Never is the hive so beautiful, so supplied with riches as when they turn their backs on it forever. In the whole range of animal life where can you find a similar sacrifice? It transcends human morality. This decree of the spirit of the hive will remain incomprehensible to the mind of man. We must believe this is a well-considered sacrifice of the present generation for that which is to come. Just how that small percentage of the population that must remain is selected is also a mystery. Somehow for days before the great exodus they seem to have accepted their orders, for they maintain the systematic labors

of the hive as well as their depleted numbers will permit. They feed the thousands of children, go to the fields for forage as they have done for weeks and seem to be unaffected by the excitement that has taken possession of their sisters, who rush wildly about the hive, pour forth from the entrance for short and unplanned flights. But the hour is come! A roar as of rushing waters is heard in the apiary. I seize my smoker, pick up a new hive that is filled with frames containing carefully wired full sheets of foundation, and call my friends to witness the greatest scene that is ever enacted in the apiary. As we approach the hive, we see a multitude of bees pouring forth and upward, the several bees of the throng darting hither and thither, the myriad transparent wings waving furiously and producing a volume of sound that terrorizes the stranger. We walk into the midst of the revolving throng that, catching the sunlight, resemble flying flecks of gold, and not one eye of the ten thousand that adorn the head of each bee of the 70,000 that circle about our heads seems to take notice save to pass us by. All seem bent to a higher purpose than the molestation of any creature.

I look carefully in the grass before the hive and on the alighting board and find no queen. She cannot be in the air for her wings are clipped. This proves in this case that the queen did not lead the swarm forth. In a few minutes I point her out at the front of the hive. She seems excited, the golden beauty. She runs along the board, raises her wings, but she cannot rise to follow her children. So she hurls herself into the grass. I pick her up gently and let her run into a queen cage. Then quickly I lift the old hive from the foundation and place it about six feet to one side and place the new hive on the old foundation, and then I bring the super from the old hive back to the new hive. The caged queen is now taken from my pocket, and as I stand in the throng of bees, those near me locate their queen and quickly alight on my hand. Not one sound have I heard nor can I believe that any smelling organ is sensitive enough to catch any odor she might give forth, but by some signal or sound the information seems to pass through the mighty host. You can easily see them descending to the new hive and many are passing in. I release the queen and she marches into her new home, as the bees crowd around her, and in less than five minutes the swarm has taken up their new abode on their old stand. The bees of the swarm come into their new home, loaded with honey; the last act before leaving the old hive was to load up with honey to have something with which to begin housekeeping.

This method for handling a swarm has given wonderful results, as

the bees, not having storage cells in their new hive, begin to store at once in the supers and the seasoned field bees that had been assigned to duty in the old hive will now join the swarm. I took 210 lbs. of comb honey from the supers over such a swarm a few years ago.

The ingenuity of the worker bees is now to be taxed to the limit. They are in an unfamiliar enclosure, which is complicated by these frames containing the strange curtains of foundation. There is not a cell to store honey in, and the queen in her eagerness to take up her duties is already laying eggs on the floor. These shrewd and tireless workers are equal to the task. One crew takes the job of cleaning up. Another crew with their wonderful bee glue, propolis, begins at once to seal up the cracks, but the essential crew of the new regime gets ready to make the wax, which is the bees' building material. After sizing up the situation, some of the wax makers climb to the highest point in the middle of their enclosure, fasten themselves by their feet to a suitable support, while others following them cling as if by clasped hands, thus making a curtain of bees from the top to the bottom of the hive. These bees become very quiet, but they must be concentrating all their internal energy on their important task, for soon they literally "sweat" wax. The wax appears in white masses in small cups on the underside of the abdomen. When a bee has prepared a good supply, she gently releases herself from the curtain of bees and goes up to the top of the hive and sticks her wax on the frames and then assumes her place again in this marvelous curtain of bees. It is supposed that they must thus pile up to secure a temperature sufficient for waxmaking. As the wax accumulates the builders begin their marvelous construction work. They take advantage of any feature in the hive, and after careful examination of the foundation they adopt it as the base work of their comb building. Quickly the hexagonal building arises, each cell being constructed exactly opposite one that faces in the opposite direction, thus being placed base to base. They make no mistake in the altitude of these cells. This comb of cells must hang between similar combs and there must be left a one-half inch space between the tops of the cells in adjacent combs. Although they generally bring down one double comb at a time, they rarely ever make a mistake in the thickness. In a single night I have known these faithful builders to complete two full combs, provided they have the foundation to build on. This foundation referred to is made of bees wax and the bases of the cells are in size and shape almost identical with those the bees would construct. The enthusiasm and system with which the swarm takes up the work of the new home is one of the marvels of animal life.

THE ARRIVAL OF THE NEW QUEENS

We may well leave this swarm, convinced that it can handle the stupendous tasks before it, and turn back to the hive that was abandoned. So great is the loss of bees, especially, when the method mentioned above is employed, that it may be best to place the old hive on top of the new hive for three or four days until enough young workers are hatched to care for the brood. A queen guard, however, must be placed between these hives. The old hive must be moved back before the sixth day, for the time of the arrival of the first new queen is at hand. When we look within the old hive, we find all the queen cells capped save one. This one has been cleaned on top and made as thin as paper by the trusty workers that have in eager expectancy done all in their power to prepare for the coming of their young queen, the hope of the hive. She is now gnawing away at the lid of her prison. At last her head appears and slowly with the help of her guardians she crawls out. She is weak and tender, but she is caressed and cleaned by her faithful attendants, who seem to wait on her every step. She soon is walking on the comb, but she is suddenly seized with a strange restlessness. She must sense the presence of rival queens, although they lie helpless in their cradles. Her first task is to dispose of them. She carries a curved stinger quite unlike those of worker bees and she uses it only on a rival queen. If the spirit of the hive has not decreed a second swarm, the queen's attendants seem to encourage her on her mission of wrath. She seeks out the queen cells, one by one, and when she has torn a ragged hole in a cell, she pierces the poor helpless queen with the deadly weapon and the undertakers have a victim for a royal funeral. Should the queen be destined by hive orders to take out a second swarm, she will find her way blocked by the guards when she tries to destroy her rivals. If in her fury she attempts to break through the guards, she may be roughly handled. Then she in her passion wanders aimlessly over the combs, giving vent to a weird cry known to every bee keeper. Maeterlinck describes it as resembling the note of a "distant trumpet of silver." This war cry of the queen has a strange influence on the whole hive, and it may often be heard in the late afternoon for four or five days. The workers pile extra wax on the queen cells to prevent the emergence of the queens, until the young queen goes forth with the second swarm. They do not like for two queens to meet in the hive. They may fear the result of the royal duel which is sure to take place.

THE NUPTIAL FLIGHT

In five or six days the virgin queen is driven under the mysterious impulse of love to take the most serious hazard of her life. If she is seeking a male as a lover she should find him with ease, for there are four or five hundred greedy, boisterous, lazy specimens in her hive. No! Her lover must be put to a supreme test. He must prove himself on wing, the strongest, the most ardent, the swiftest of the thousands that live only with the hope that they may be accepted by the queen. She is now seen on the board in front of the hive. She flies in the air in ever widening circles about the hive. She must know well every landmark about her home, for to be lost now would be the worst known calamity that could befall the colony. Suddenly she flashes into space and perchance she leaves in her wake some delicate perfume that stirs every drone in the apiary, and they stream after her in hot pursuit. Higher than any bee ever flies she goes, and somewhere in the upper air the one drone of the multitude meets his queen and then falls dead. The marriage of the queen has been accomplished and she returns to her home, never more to venture forth unless she must follow a swarm. She is now ready for her duties in the hive, and she carries in her spermatheca spermatozoa that will fertilize all the eggs she may lay in three or four years, even though at times of heavy honey harvest she can lay from 2000 to 3000 per day.

She appears like another bee now. She is much larger, more gentle, more stately in her walk and ways. In three days, she is generally laying eggs in the cells that are ready for her.

THE DOOM OF THE DRONES

Bee keepers and the worker bees can never agree on the question of rearing drones. The only really wasteful habit that the workers possess is this production of a horde of useless bees that consume many times their weight of honey and contribute not one good thing to the economy of the hive. Every plan that has been used to prevent them is to some extent frustrated. In the early honey season, when there is a prospect of a swarm, a strange instinct drives the workers to provide some means of rearing a large number of these male bees that simply encumber the hive. The workers will put up with their uncleanly habits and wasteful lives in order that there shall be a sure chance of impregnating the young queen they expect to rear. This prodigality is in the interest of the race. When the honey harvest is

past and stores are running short and the worker bees have decided that no new queen will be needed, the disposition of the workers towards the drones is suddenly changed. The order passes through the hive, and the day of execution is set. One by one, these drones are dragged forth. Some have their wings and legs torn away. Some are killed outright. The guard bees at the entrance fall upon those that seek to enter and drive them back with irresistible fury. The doom of the drones has fallen. Strange to see how these gentle ladies of the hive lay rough hands on the men and drag them to their death. If our government should ever fall into the hands of the women, need we wonder at the state of us men when it becomes known that we are of no further use.

Fighting Disease

There are several enemies of the honey bee. In this country we have only three that cause severe losses. It may be well to encourage bee keepers by telling them of a remedy in each case. The wax worm is a most deadly enemy in the weakened hive. When these worms once get possession of a hive, they will destroy the comb more rapidly than the bees can build it. Remedy: Strengthen the hive by adding frames of capped brood from strong colonies and be sure that you have a vigorous Italian queen. Italian bees will not live in the same hive with the wax worm.

The European foul brood causes serious loss in many sections. This is due to a germ that destroys the larvae bees. Fortunately it is not transmitted in honey. Remedy: Cut off brood by removing the queen for two weeks, and increase young bees by adding capped brood from healthy hives. Then introduce a vigorous Italian queen. Keep strong in Italian blood and they will clean up this foul brood.

The American foul brood is more serious because the germ is transmitted in honey as well as in larvae and it has been the rule to destroy the diseased hive. This has been attended with frightful loss. Within two years an adequate remedy has been discovered: It consists in treating the diseased combs with an alcoholic solution of sodium hypochlorite.

Honey

After all the most interesting thing in the bee hive is that delicious food prepared by the bees. It must be the best of all foods, for the Bible distinctly tells us that the Paradise, the far away home of the

Soul, is flowing with milk and honey. This may be figurative language, but we must admit that honey would not have been chosen if it did not represent the best and purest of earthly foods.

Chemical analysis shows that honey consists largely of invert sugar, glucose and fructose, together with a small quantity of water, mineral matter, essential oils that impart the flavor, and a trace of formic acid that preserves it. Even when bees are fed on sucrose, it is inverted and in few cases has sucrose ever been found in honey. We see then that honey is a predigested sweet. In the bees' crop, the difficult process of hydrolysis has been effected and thus only the simple sugars are found in honey which are easily digested. This may account for the fact that bee keepers who eat much honey attain great age. Langstroth, C. C. Miller and A. I. Root are conspicuous examples, all having passed their four score years.

Honey is made from the nectar of flowers principally, and its flavor is as varied as the fragrance of the flowers. There is a honey to suit the palate of every one. The clovers and alfalfa all yield large stores of honey, but white clover is the queen of all honey plants, producing honey in many localities for a period of thirty days. The flavor of this honey is truly delicious. In New York buck wheat yields a large crop in the month of August. This honey is dark and rather strong in flavor, but is a great favorite. One apiary in New York has placed on the market two tons of extracted buckwheat honey in a single season. In Florida, the tupelo, or black gum, yields a large supply. Mississippi markets much tupelo honey and *melilotus* honey. Michigan is famous for raspberry honey, North Carolina for its sourwood, West Virginia produces large quantities of basswood honey, sometimes called lynn honey. This honey is as white as water and has a rich aromatic flavor. The honey flow from basswood rarely lasts over ten days. We have not time to tell of the various honey producing plants, though it would be interesting to speak of the different properties of the honeys known on the American market.

The conditions that control the honey flow have never been accurately determined. It often happens that the bees will not visit a single flower of some choice honey plant, though the flowers are to be found in abundance. I have seen the fields white with white clover bloom for two weeks in June and not a bee could be found on a blossom. There was no nectar in the blossoms. Then suddenly the bees start to work on the white clover and for days from early morn till twilight the workers are falling in front of their hives loaded with this rare nectar. Whether it is temperature, moisture or soil conditions has never been determined.

Many questions are asked about honey-dew. This is a sweet fluid deposited on leaves of certain trees like oak, tulip and hickory by aphids. Bees love to carry it to their hives, but it makes a strong flavored, inferior honey and should never be marketed.

There are so many things to tell of the bees, but we must not weary you. It would be profitable to discuss the part that the honey bee plays in pollination of flowers, particularly in pollination of fruit blossoms and berry blossoms.

As proof of the industrial importance of the bee, I should like to report the phenomenal yield of three hundred picked hives in a California apiary last season. Yield was 60,000 lbs. Now, when we remember that this big store of delicious food was gathered from the nectar of flowers, which, without the service of the bee, would be entirely wasted, you see what an economic factor this little insect is.

May I give some idea of the vast amount of work done by the bee in gathering this honey. Careful experiments show that it takes 150 heads of white clover to produce one gram of honey; 7,500,000 flower tubes of white clover are required to yield two pounds. If a bee can carry the nectar of only 25 flower tubes, you can easily figure the number of bees and the number of visits required to make one pound of honey. When we think of the vast stores that are gathered each year, we must respect the industry of these tireless workers of the hive, and, if we could, we would crown them every one queens and make for them at the end of their ninety days a paradise of endless rest and joy.

THE BEE AND SCIENCE

In concluding this inadequate portrayal of the life and achievements of the honey bee I am tempted to mention a few of the contributions to scientific accomplishment in which the bee has anticipated man.

She has elaborated a poison so potent that a single drop injected under the cuticle is sufficient to make the victim confess that the bee has put the apothecaries to shame.

Long before Pasteur laid the foundation for asepsis, the bee had prepared and used antiseptics. She had learned to can her delicious food products so they would defy the common threat of fermentation, decay and putrefaction by employing clean containers, exclusion of air, and germicides.

Before the chemist had shown the great possibilities of colloidal chemistry in its application to the manufacture of valuable plastics, the bee had learned to make and use wax and propolis.

The control of sex, which, in spite of repeated efforts of biologists, has never been accomplished by man, has virtually been achieved by the bee.

She has prepared a food that has in her hands produced changes in in development that surpass anything that the chemist has done. Royal jelly may well supply a field for vitamin researches. The bee had learned to employ in this strange combination of nutrients elements far more potent than vitamins and it is possible that the chemists will some day discover substances that produce results more wonderful than those produced by vitamins.

You must confess that we have much to learn from the bee and, in spite of the advancement of bee-culture, made possible by the exhaustive studies of such men as Dzierzon, Langstroth, Cook and Quinby, there remains much to be done. Trusting that you are now ready to give the *Apis mellifica* the high place she deserves, I commend her to the study of all who love science.

VARIATION OF PROTEIN CONTENT OF CORN

Paper IV

By H. B. Arbuckle and O. J. Thies, Jr.

Synopsis of Paper I[1]

1. A rapid Kjeldahl method for the determination of nitrogen in corn; average time of digestion, 35 minutes.
2. Report of analyses of certain varieties chosen for experiment.
3. Corn grown in North Carolina from West Virginia seed showed lower protein.

Synopsis of Paper II[2]

1. Brief discussion of facts presented in paper I.
2. Errors arising from using varying amounts of alkali in neutralizing Kjeldahls.
3. Reports of analyses of corn grown in North Carolina and West Virginia.
4. In two samples of corn grown in North Carolina the protein content shows marked increase.
5. Two varieties of corn grown in West Virginia from North Carolina seed show different results. One gave no marked change in protein. The other, a decided increase.
6. Immature corns show low protein in every case.
7. Report of analyses of additional varieties.

Synopsis of Paper III[3]

1. Presentation of analyses to show the effect of fertilizers on protein content of corn.
2. Comments on results.
3. Discussion of variation of protein content in different ears, different parts of the same ear, and different grains of each portion of the ear.

Introduction

This work on the protein content of corn was undertaken with the hope that we might discover the factors that control the protein content of corn. A number of varieties of corn were grown in West Virginia and North Carolina, and analyses were made to discover the influence of climate on the protein. It was assumed that the time for complete maturity in climates so different would not be the same. As we have

[1] This Journal, **38:** 84. 1922.
[2] This Journal, **39:** 56. 1923.
[3] This Journal, **40:** 176. 1924.

shown that immature corn always shows smaller protein content, it was thought that with Carolina seed of corn requiring a long period of development would show a lower percentage of protein when grown in West Virginia, because, in this locality, it would be difficult to secure full maturity; while varieties moved from West Virginia might show an increase in the percentage of protein except in the case of a short period corn. Our results were not all consistent with this hypothesis.

In our last paper we included reports on corns that were grown with different fertilizers. We found very slight changes due to use of large quantities of complete fertilizers, phosphoric acid, and sodium nitrate. The samples grown over sodium nitrate did in each instance show a slight increase of protein, but it was in no way proportionate to the nitrogen supplied in the fertilizer.

Our conclusion based on our experiments of 1923 was that fertilizers had no appreciable effect on protein content.

The difficulties encountered in these researches were greatly multiplied by our discovery that the different ears taken as samples often showed a greater range in protein than samples of different varieties. This made it necessary to take a larger number of ears for samples. Then we found quite a difference in protein in different parts of the same ear, which made it necessary to use grains from the same section of each ear.

We had one sample of corn that we had steadily increased in protein until we had changed the amount from 6.82% to 10.36% protein. This sample, Golden Dent, is a long period corn, requiring about 130 days for full development. It is difficult to secure over 120 days in West Virginia for corn development. This particular year, 1922, gave a longer period than usual, but the result was unexpected. What has produced this profound change in protein of this particular corn is unknown. We had hoped to present further analyses of this corn from a sample grown from this high protein seed last summer, but unfortunately the crows took up most of the sprouted corn, and a late start, together with an early frost last fall made it impossible to secure a mature sample. So this experiment must be undertaken this summer.

EXPERIMENTAL

We thought it advisable to repeat our experiments with fertilizers. Consequently, last summer, 1924, two varieties of corn were grown in West Virginia with the same quantities of fertilizers that we used the year before, and we present the analyses in the tables below. These

samples are designated CCC, CCC-1, CCC-2, and CCC-3, for Silver King, which is the same corn we have studied from the beginning; and N, N-1, N-2, and N-3 for White Cap, which was grown from West Virginia seed for the first time on the farm in West Virginia where the other experiments were conducted.

We also present analyses of White Cap, grown the second time in North Carolina, from North Carolina seed. This was a corn introduced from West Virginia, and in our last paper we reported a slight increase in protein, which might have been due to sodium nitrate used as fertilizer. You will note in our tables that we took samples grown on rich land, GGG-r, and on poor land, GGG-p. The latter samples show a falling off in protein, which, we believe, is due to having included certain ears that, for some unknown reason, were low in protein. We give the analyses of four ears of this GGG-r corn which would cut down the protein content of our twelve ear sample distinctly. Here we are up against the difficulty mentioned above: We have observed a peculiar change in this White Cap corn, which is a yellow corn, with white caps on the grains. The corn is changing to a white corn, and we know that it is not due to cross fertilization from white corn, as there was no white corn grown within a mile of this corn.

You will observe from our tables of protein content of corns grown under the various conditions of fertilization, that we have a striking confirmation of our work last year on fertilized corns, with the exception of CCC-3, which shows, for some reason, a distinct slump in protein. There must be some error in this particular experiment, but we have failed to locate it. The influence of fertilizer in influencing the percentage of protein is negligible.

To demonstrate the variation of protein in different ears, we thought it worth while to show the analyses of eight of the twelve ears used for the CCC sample. Note the wide variation in ears no. 7 and no. 8. Manifestly, this points to interesting facts for which we have found no explanation.

RESULTS OF ANALYSES

TABLE I

Analyses of White Cap Corn, grown in West Virginia, from seed grown in West Virginia. Seed taken from a sample different from that which supplied seed for GGG. Protein content of seed, 9.08%

	N-1 COMPLETE FERTILIZER, 8-2-2; 300 LB.	N-2 PHOSPHORIC ACID, 16 PER CENT 300 LB.	N-3 SODIUM NITRATE 200 LB.
	per cent	*per cent*	*per cent*
Nitrogen:			
No. 1	1.457	1.479	1.515
No. 2	1.477	1.488	1.529
No. 3	1.519		1.527
Mean	1.484	1.484	1.524
Protein	9.28	9.28	9.53

TABLE II

White Cap Corn, grown in North Carolina from seed produced in North Carolina in 1923. Protein content of seed, 10.55%

	GGG-r GROWN ON RICH LAND	GGG-p GROWN ON POOR LAND
	per cent	*per cent*
Nitrogen:		
No. 1	1.402	1.212
No. 2		1.252
No. 3	1.430	1.249
Mean	1.416	1.238
Protein	8.85	7.74

TABLE III

Analyses of separate ears of sample GGG-r, White Cap Corn, given described in Table II, above

	GGG-r NO. 1	GGG-r NO. 2	GGG-r NO. 3	GGG-r NO. 4
	per cent	*per cent*	*per cent*	*per cent*
Nitrogen:				
No. 1	1.233	1.258	1.204	1.178
No. 2	1.235	1.266	1.231	1.174
Mean	1.234	1.262	1.218	1.176
Protein	7.71	7.88	7.62	7.35

TABLE IV

Analyses of Silver King Corn, grown in West Virginia from seed produced in West Virginia in 1923. Protein content of seed, 9.15%

	CCC NO FERTILIZER	CCC-1 COMPLETE FERTILIZER 8-2-2; 300 LB.	CCC-2 PHOSPHORIC ACID, 16 PER CENT 300 LB.	CCC-3 SODIUM NITRATE 200 LB.
	per cent	*per cent*	*per cent*	*per cent*
Nitrogen:				
No. 1	1.600	1.539	1.555	1.356
No. 2	1.593	1.536	1.556	1.365
No. 3	1.626	1.546	1.542	1.361
Mean	1.606	1.540	1.554	1.361
Protein	10.03	9.63	9.71	8.45

TABLE V

Analyses of eight separate ears taken from sample CCC of the silver King corn described in Table IV, above

	CCC NO. 1	CCC NO. 2	CCC NO. 3	CCC NO. 4
	per cent	*per cent*	*per cent*	*per cent*
Nitrogen:				
No. 1	1.493	1.514	1.522	1.455
No. 2	1.555	1.501	1.509	1.442
Extra	1.527			
Mean	1.525	1.508	1.516	1.449
Protein	9.53	9.43	9.48	9.06

	CCC NO. 5	CCC NO. 6	CCC NO. 7	CCC NO. 8
	per cent	*per cent*	*per cent*	*per cent*
Nitrogen:				
No. 1	1.425	1.623	1.343	1.689
No. 2	1.464	1.669	1.278	1.677
Extra		1.673	1.383	
Mean	1.445	1.655	1.335	1.683
Protein	9.03	10.34	8.34	10.51

COMMENTS, CONCLUSIONS AND SUMMARY

The authors are quite well satisfied that we cannot change the protein of corn by use of fertilizers.

We are also convinced that in any variety of corn there is so much of mixed inheritance that we cannot hope to find the protein very constant from ear to ear.

We are further convinced that should we undertake the raising of the protein content by seed selection, we must undertake the analysis of the different grains on the ear. It cannot be done by ear selection. As far as we know, no one has ever undertaken this arduous task. We believe it offers great possibilities.

Thus far we can say that climate, or period of development determined by climate, seems to have some influence on protein; fertilizers have no appreciable effect, and change in soil has little effect. It begins to appear more probable that a variety of corn with constant inheritance may have an almost constant protein content. We see the importance of further experimentation.

Summary: 1. Further tests on influence of fertilizers indicate that they have slight effect on protein.

2. Analyses of several ears of a given sample show a distinct variation in protein, which suggests a confused inheritance in our usual varieties.

3. Suggestion offered as to importance of increased protein in seed selection of grains rather than ears.

DAVIDSON COLLEGE,
DAVIDSON, N. C.

ERRATUM

In paper III,[4] the percentage of nitrogen in the grains of corn taken from the middle of the ear of White Cap Corn, which reads 1.46%, should read 1.513% nitrogen. The percentage of protein, however, is correctly reported.

[4] This Journal, **40**: 178. 1924.

THE NEW WORLD OF THE ATOM AND ALBERT EINSTEIN[1]

By Archibald Henderson

Plates 1–4 and 9 Text Figures

I

"A greater than Einstein is here: Niels Bohr." These are words recently spoken to me by one of the greatest living authorities on the electrical structure of matter. Three remarkable figures are associated with the recent extraordinary efflorescence of theory connected with the nature of the atom and its constituents. During the years 1912-13 there were working in the laboratory of Professor Ernest Rutherford at the University of Manchester two brilliant young men: G. W. T. Moseley, an Englishman, and Niels Bohr, a Dane. In a series of important investigations, Rutherford had already shown that the atom is nuclear in structure, with a surrounding cloud of free electrons. From a study of the frequency of the lines in the Roentgen ray spectra, Moseley showed that there was some constant for atoms which increased by equal amounts from element to element in the periodic system;[2] and this constant was seen to be nothing else than the nuclear charge. Reasoning from the complex spectrum of hydrogen, which has the simplest possible electrical structure, Bohr concluded that the complexity of the spectrum is due, not to the complexity of the atomic structure, but to the variety of modes in which an electron can emit radiation. By applying the Quantum Theory to explain the relation between the energy of the electron and its frequency of radiation, in falling from one orbit to another, he laid the foundation of the epochal

[1] For personal assistance and the placing of an immense amount of data at my disposal, while I was at Cambridge University, England, I am greatly indebted to Sir Ernest Rutherford, Sir J. J. Thomson, Dr. F. W. Aston, and Messrs. C. T. R. Wilson and P. M. S. Blackett. I was also so fortunate as to consult Professor Albert Einstein of the University of Berlin regarding certain aspects of Relativity in connection with atomic structure.

[2] Moseley's law stated that the frequency of the characteristic Röntgen radiations of the elements is proportional to the atomic number. Millikan has admiringly spoken of "the extraordinary work of a brilliant young Englishman, Moseley, who, at the age of twenty-seven, had accomplished as notable a piece of research in physics as has appeared during the last fifty years." Moseley fell a victim of the World War, being instantly killed in the trenches in 1915.

theory of orbits which has won him world renown. During the past decade, he has developed his theory of the electrons so completely that it is now possible to gain a very fair conception of the movements of the electrons in the atoms of all substances, in an undisturbed or unexcited state, even for atoms with as high an atomic number as radium (88) or uranium (92). These results are certainly extraordinary in character; and in their higher developments the investigations draw upon the theories of Einstein on Relativity, of Planck on Quanta, of Lorentz on the electron, of Ritz, Balmer, Lyman and others on spectra.

The number and variety of researches, dealing with the atom and its structure, now going forward, in the United States, in Europe, in Japan and elsewhere, assure the coming of new and striking developments in the near future. Hypotheses long ago tentatively advanced have at last been confirmed by experiment; facts regarding the structure of the atom and its electrical constitution have finally been established. The orbital theory for the free electrons in the atom, while resting in part upon certain hypotheses as yet unverified by experiment, has been so uniformly successful in explaining puzzles and harmonizing discordant facts, that it has attracted the attention of the entire civilized world. A survey of atomic and electrical theories and of recent developments in molecular physics, may clearly exhibit the nature and significance of the newer discoveries regarding the fundamental properties of matter.

II

The newer atomic theories require a new name for the atom (ἄτομος the "indivisible"). No longer can it be accurately termed the "ultim-atom" of physical science to the twentieth century. We now feel sure that the atom is nuclear in structure in the interior, with rings of free electrons moving about the nucleus in complicated orbits. Some sort of atomic theory has been known ever since, and doubtless prior to, the time of Democritus (400 B.C.). According to Democritus, all changes are due to the combination of molecules, the only existing things being atoms and empty space; the atoms are infinite in number and infinitely various in form; they strike together and the lateral motions and whirlings which thus arise are the beginnings of worlds. Although Aristotle was an anti-atomist and exercised powerful influence upon the minds of men even down to the Middle Ages, he did not succeed in overthrowing the atomic theory. It was upheld by Epicurus (300 B.C.) who introduced the term "atom;" and by Lucretius

(c. 75 B.C.) in his *De Rerum Natura*. The atomic theory gradually spread, following the impetus given to the new physics by Galileo (1600); and it was considerably forwarded by progress in the study of chemistry. Nor should it be forgotten that Newton suggested that matter was composed of atoms which were likened to "hard massy balls." Robert Boyle (1627–1691), who developed clearly the notion of a chemical element, relied in his deductions upon a theory of matter atomic in its nature, and he certainly regarded a gas as consisting of atoms in multiple proportion.

Credit for the first definite formulation of the atomic theory must be assigned to John Dalton, who in 1803 enunciated his law of multiple proportions. While Dalton had to resort to certain arbitrary assumptions and was unable to carry out his analyses with complete accuracy, thus leading to results for the ratios of the atomic weights of the atoms at variance with those we now know, nevertheless it is indisputable that his atomic theory is the firm foundation upon which modern chemistry is built. Avogadro, the Italian, in 1811 put forward the hypothesis, now known as a law, that equal volumes of all gases at the same temperature and pressure contain the same number of molecules; an experiment showed that the molecules were composed of atoms, sometimes consisting of but a single atom. The famous "Brownian Movement," discovered by the English botanist, Brown, in 1827 eventually led to the conclusion that all liquids contain small particles in tumultuous motion. These small particles, each of which might be an agglomeration of millions of molecules, behave in many respects like the much smaller molecule. In their kinetic theory of gases, Clausius and Clerk Maxwell asserted that the molecules of a gas are in continuous agitation, colliding with each other and with the walls of the containing vessel. Theory and experiment ultimately pointed to the fact that the atoms of matter, whether in the solid, liquid or gaseous form, are in continuous agitation and irregular motion. Valuable as the theory was, it threw no light on the structure of the atom or molecule, or of the forces between them.

A revolutionary discovery, which was later to throw light upon the inner structure of the atom and its chemical properties, was the enunciation of the "periodic law" of the elements by the Russian chemist, Mendeléjeff, a discovery independently made by the German, Lothar Meyer. In this scheme, the elements are arranged according to their "atomic weight;" and many of the elements are found by measurement to be almost exact multiples of the hydrogen atom. By choosing the

number 16 as the atomic weight of oxygen, the atomic weights of many of the elements are whole numbers; and the atomic weight of the lightest element, hydrogen, becomes slightly more than unity, viz. 1.008. Aston, of Cambridge University, has recently shown by exhaustive investigations that in many cases where the atomic weight comes out

TABLE I

Elements and Isotopes

ELEMENT	ATOMIC NUMBER	ATOMIC WEIGHT	MINIMUM NUMBER OF ISOTOPES	MASS-NUMBERS OF ISOTOPES IN ORDER OF INTENSITY
Hydrogen	1	1.008	1	1
Helium	2	3.99	1	4
Lithium	3	6.94	2	7, 6
Beryllium	4	9.0	1	9
Boron	5	10.9	2	11, 10
Carbon	6	12.00	1	12
Nitrogen	7	14.01	1	14
Oxygen	8	16.00	1	16
Eluorine	9	19.00	1	19
Neon	10	20.20	2	20, 22
Sodium	11	23.00	1	23
Magnesium	12	24.32	3	24, 25, 26
Aluminium	13	26.96	1	27
Silicon	14	28.3	2	28, 29, (30)
Phosphorus	15	31.04	1	31
Sulphur	16	32.06	1	32
Chlorine	17	35.46	2	35, 37
Argon	18	39.88	2	40, 36
Potassium	19	39.10	2	39, 41
Calcium	20	40.07	2	40, 44
Scandium	21	45.1	1	45
Titanium	22	48.1	1	48
Vanadium	23	51.0	1	51
Chromium	24	52.0	1	52
Manganese	25	54.93	1	55

not a whole number, there is really a mixture of two different elements, each of which has a whole number for its atomic weight. Such elements are called "isotopes" (ἴσος, τόπος) a name suggested by Soddy, since they appeared to occupy the same place in the periodic table. Such substances, of different atomic weights, have the same spectroscopic properties, the characteristic lines of the different substances occupying the same place in the spectrum.

The table of atomic weights now employed differs somewhat from Mendeléjeff's table, both in the number and the arrangements of the elements. With each element, it must be noted, there is associated a number called the "atomic number," which indicates its position in the series with respect to increasing atomic weight. There are a few exceptions to this rule, considerations of chemical affinity requiring certain interchanges of the natural order.[3] The elements, a few of which appear in the table (table I) giving some of Aston's recent results, are 88 in number (or 92 counting gaps), beginning with hydrogen (atomic number 1) and ending with uranium (atomic number 92). For reasons which will develop subsequently, the significance in recent years has shifted from atomic weight to atomic number.

III

The Atomic Theory clearly gave rise to the conception that there must be some fundamental unit out of which all the elements and the chemical compounds are built. The human mind revolts against the notion that the universe must be built up out of eighty-eight different sorts of things. Shortly after Dalton developed his atomic theory, an Englishman, Prout, advanced the hypothesis (1815) that hydrogen atoms were the fundamental units, the "bricks" out of which the atoms of the other substances were built. This was a reasonable hypothesis since, within the limits of experimental error, many of the atomic weights were multiples of that of hydrogen—12 for carbon, 14 for nitrogen, 16 for oxygen, and so on. More accurate determinations, however, showed apparently that Prout's theory had to be abandoned. It has been suggested that the usual atomic weights which in many instances vary from integral values should rather be called "mixture-weights." The striking characteristic of elementary atomic weights, that of being integral, once more restores Prout's hypothesis to its position of honor—although, as we shall see subsequently, new complications have been introduced by recent discoveries in electricity.

"By superposing upon the molecular and the atomic worlds of the nineteenth century a third electric world," says Millikan, the twentieth century has "sought to reduce the number of primordial elements to not more than two, positive and negative electrical charges." It was about 1747 that Benjamin Franklin introduced the terms "positive"

[3] Thus argon and potassium, for example, have atomic numbers 18, 19, but atomic weights 39.88, 39.10. A more crucial reason for such interchanges will appear later.

and "negative" to distinguish the two different kinds of electrification. There can be little doubt that Franklin believed in the granular structure of electricity, since he clearly recognizes the existence of an electrical particle or atom in these words: "The electrical matter consists of particles extremely subtle, since it can permeate common matter, even the densest, with such freedom and ease as not to receive any appreciable resistance." No real advance in the theory of the atomic structure of electricity was made until 1833 when Faraday, in his famous experiments on the passage of electricity through electrolytes, virtually proved that electricity was atomic in character and that the charges carried by the individual ions[4] were integral multiples of a fundamental unit of charge. The trend of thought for the next half century and more, however, was away from the conception of electricity as a substance, concentrating rather upon a study of the hypothetical aether as the transmitter of electrical stresses and strains. Although Clerk Maxwell in 1873 is willing "for convenience" to call the constant molecular charge revealed by Faraday's experiments "one molecule[5] of electricity," he expressly disclaims any belief in its physical significance. In 1871 Wilhelm Weber definitely proposed the theory of the atomic structure of electricity; and G. Johnston Stoney (1874) not only clearly stated the atomic theory of electricity, but suggested the name "electron" for the fundamental unit of electricity, which he calculated to consist of 0.3×10^{-10} "absolute electrostatic units." In 1881 Helmholtz, following Faraday, concluded that electricity, positive as well as negative, is divided into definite elementary portions which behave like atoms of electricity. In 1883 Lord Kelvin gives strong cumulative evidence in favor of the atomic structure of matter; and in later papers accepts Stoney's conclusions regarding the atomic nature of electricity.

"The proof in 1897 of the independent existence of the electron as a mobile electrified unit of mass, minute compared with that of the lightest atom," says Rutherford, "was of extraordinary importance." A full century earlier both Laplace and Lavoisier were well aware that the hydrogen gas evolved when a metal dissolves in an acid carries with it an electrical charge; but this knowledge long remained neglected. In his investigations Stoney assumed as the fundamental unit of charge that carried by the hydrogen ion in the electrolysis of water; but Townsend was the first to show that the positive or negative charge carried

[4] An ion, from the Greek word meaning wanderer, means an electrically charged wandering atom.

[5] Clerk Maxwell uses the word "molecule" where we now use the word "atom."

by an ion in gases is equal to this charge carried by the hydrogen ion. Following the experiments of J. J. Thomson at the Cavendish Laboratory, Cambridge, on the charge and mass of electrons, R. A. Millikan made a series of brilliant investigations in the Ryerson Laboratory at the University of Chicago, to determine directly the charge of the electron, independently of its mass. By comparing the pull of an electric field on a charged droplet of oil or mercury, of exceeding smallness, he gave the classic demonstration that the elementary quantum of electricity e is $4.774\ (\pm 0.005) \times 10^{-10}$. In recognition of these and other important investigations he has recently been awarded the Nobel Prize in physics. "When we consider the minuteness of the unit of electricity and of the mass of the atom," says Rutherford, "this experimental achievement is one of the most notable even in an era of great advances." From this value of e, it is found that the mass of the electron is about 1/1835 that of the hydrogen atom; and that the radius of the electron is 1.5×10^{-13} centimeters, or 0.5×10^{-13} inches. The weight of an atom of hydrogen is about a million-millionth of a million-millionth of a gramme and a half; or since a gramme is about 1/453 of a pound, this would be about $\frac{1}{3}\ 10^{-22}$ pounds. The weight of an electron is just 1/1835 of this. The diameter of a hydrogen atom is about a hundred millionth of a centimeter, or $\frac{1}{3}\ 10^{-8}$ inches. The size of a hydrogen atom bears the same relation to the size of an electron as the earth bears to the dome of a cathedral, or as a sphere with the radius of the earth's orbit about the sun bears to the earth. The distance of the electron from the nucleus of the hydrogen atom is about 1/600,000,000 of an inch.

IV

Even before the discovery of the electron, the hypothesis had been advanced that the atom was an electrical structure composed of negatively and positively charged particles held in equilibrium by electrical forces. What are the relative rôles played by positive and negative electricity in the structure of the atom? Experimental evidence indicates that atoms of matter are built up of two electrical units, viz. the electron and the hydrogen nucleus or "proton" (from the πρωτε ὕλη of the ancients), as it is usually called when it forms part of the structure of any atom. This hydrogen nucleus carries a positive unit charge; and since its mass is 1835 times that of the electron, its radius would be only 1/1835 that of the electron—on the assumption that the distribution of electricity is much more concentrated for the proton, taken to be spherical in shape.

The first atom-models were built on the assumption that the atom is made up of concentric layers or spheres of electrons, balanced by a positive charge, equal and opposite to that carried by the electrons to render the atom electrically neutral, and distributed over the whole volume of the atom. In a paper entitled "Aepinus Atomized" (1882), Lord Kelvin considered one atom to consist of a uniform sphere of positive electrification, throughout which negative electricity was distributed in the form of discrete electrons. This type of atom-model was studied and developed with great skill by J. J. Thomson, who succeeded in showing that such models with a given number of electrons possess many properties shown by the actual electrons. A new era was ushered in with the discovery of radio-activity, and the study of the alpha and beta particles in their passage through matter.

In view of the enormous progress made in its study, it is difficult to realize that radio-activity was so recently discovered by Becquerel; and that radium, discovered by Mme. Curie, and a number of other radio-active elements have already been so exhaustively studied. Radio-active substances when exicted emit three kinds of rays—known respectively as alpha, beta, and gamma rays.[6] The alpha rays consist of particles, each of which, as Rutherford showed in 1909, is the nucleus of a helium atom; and the beta rays consist of particles which are electrons. The alpha particles travel sometimes as far as 11.3 centimeters, and have velocities from one-twentieth up to about one-tenth of the velocity of light.[7] The beta particles have enormous velocities ranging to as high as 0.998 times the velocity of light (say about 186,000 miles per second).[8] Rutherford seized on the alpha particle as a projectile for the bombardment of atoms; and by bombarding a phosphorescent screen, usually of zinc sulphide, was actually enabled to count the number of alpha rays, each of which showed a scintillation.[9] From a careful study of the scattering of alpha particles, Rutherford was led

[6] The gamma rays are of no concern to us here.

[7] The velocity of light is roughly one billion (10^9) feet per second.

[8] A close value for the velocity of light is 186,330 miles per second, and is a theoretical limit for the speed of material particles. The beta particles have the highest known velocity of any particle yet found in nature.

[9] At the moment of writing, an instrument devised by Mme. Curie is on exhibition at the Physical Exhibition at the Grand Palais, Paris. As each alpha particle from a fragment of polonium penetrates a tube, there is a luminous discharge which acts as a switch, throwing into circuit a minute electric current that actuates the loud speaker of an ordinary wireless valve receiver. A loud tick-tick thus announces the discrete disintegration of polonium.

to announce his nuclear theory of the atom—a story best told in his own words:

> When a pencil of alpha rays falls on a thin film of gold, for example, the great majority of the particles pass through with little absorption. A few, however, are found to be so scattered that they are turned back through an angle of more than a right angle. Taking into consideration the great energy of motion of the alpha particle (velocity of 10,000 to 20,000 miles per second), such a result is as surprising as it would be to a gunner if an occasional shot at a light target was deflected back toward the gun. It was found that these large deflections must result from an encounter with a single atom. . . . . If the forces causing the deflection were electrical, it was at once evident that the electric field within the atom must be exceedingly intense. The distribution of positive electricity assumed in the Thomson atom was much too diffuse to produce the intense fields required.

Accordingly, Rutherford advanced the epochal theory of the nucleus, which has proven so extraordinarily fertile of results in very recent years. He inverted the rôle of positive electricity, supposing it not to be distributed through a field comparable in size with the "sphere of action" of the atom, but to be concentrated in a very minute volume or nucleus; and further assumed the greater part of the mass of the atom to be resident in this nucleus.

The atom has been not inaptly likened to a "planetary system," because of the operation of Coulomb's Law (1785), according to which the repulsions or attractions between two electrically charged bodies are directly as the product of the charges and inversely as the square of the distance between them. This is the electric analog of Newton's law of gravitation, except that whereas the planets of the solar system attract one another, the electrons in an atom, since they all have negative electricity, repel one another.[10] In the case of the nucleus and the electron, the law of attraction is the same as that of the solar system: at half the distance there is four times the attraction, and so on. For the hydrogen atom, the diameter of the nucleus is of the order of 10^{-13} centimeters, and since the diameter of the atom is of the order 10^{-8} centimeters, the nucleus is about one hundred thousand times as small (linearly) as the whole atom. It is clear then that the atom, like the solar system, is empty; and by its so-called spherical boundary is meant the outer limits of its revolving electrons. If in the helium atom, for example, the nucleus were represented by a small marble, its planetary

[10] It seems scarcely necessary to remind the reader that unlike kinds of electricity attract, like kinds repel. The nucleus (positive) of an atom, for example, attracts an electron (negative).

electrons would be represented by somewhat smaller marbles revolving around it at the distance of a mile. The diameter of the nucleus of the heavier atoms is put by Rutherford at 5×10^{-13} centimeters, or about one-sixth of a million-millionth of an inch. The nucleus of Radium C has a diameter of 3×10^{-12} centimeters, or about one million-millionth of an inch.

In view of the fact that an alpha particle generally goes through 500,000 atoms without approaching the central nucleus more than two or three times, the chance of striking a nucleus head on is very small. Only one alpha particle in a million is able to liberate a hydrogen atom from nitrogen. Even in the case of heavy elements, only one alpha particle in about 10,000 makes a close collision with the nucleus. Despite these great difficulties, this method of bombardment by alpha particles virtually established the nuclear theory. Convincing support

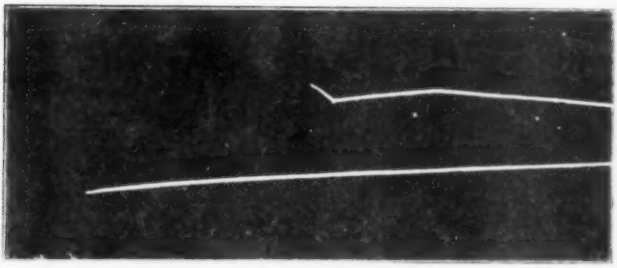


Fig. 1. Track of Alpha particles showing sharp deviations (C. T. R. Wilson)

has been given the nuclear theory by the remarkable photographs made by C. T. R. Wilson, Harkins, Shimizua, Blackett and others, following Wilson's valuable discovery of a method for taking such photographs. These photographs plainly show the paths of alpha particles (helium nuclei) and beta particles (electrons) and the deflections caused by their collisions with atoms. In figure 1, we see the track of an alpha particle; its two sharp bends indicate that at each bend occurred a close encounter with an atom. This supports the nuclear theory, since the electric field within the atom must be concentrated and intense in order to induce such sharp deflections in the path of the alpha particle, which ordinarily is quite straight (figs. 1, 2). In figure 2 are seen the initial portions of two alpha ray tracks (g and g′), showing the short beta ray tracks radiating from the path of the alpha particle with a velocity here of about 3.5×10^9 centimeters, or one-ninth the

velocity of light—about twice that of the alpha particle. In plate 2, are shown the paths of beta particles produced by the passage of X-rays through air, according to the "cloud method;" and these tortuous paths clearly result from collisions with the atoms. In plate 2, we have a clear comparison between the paths of fast and slow beta particles, the fast particle moving in a straight line. In figure 3 we have a double

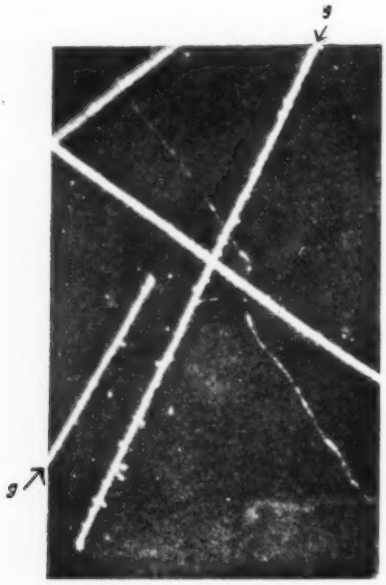


Fig. 2. Alpha ray tracks, stereoscopic (C. T. R. Wilson). Four-fold enlargement of original objects. Courtesy Proceedings Cambridge Philosophical Society.

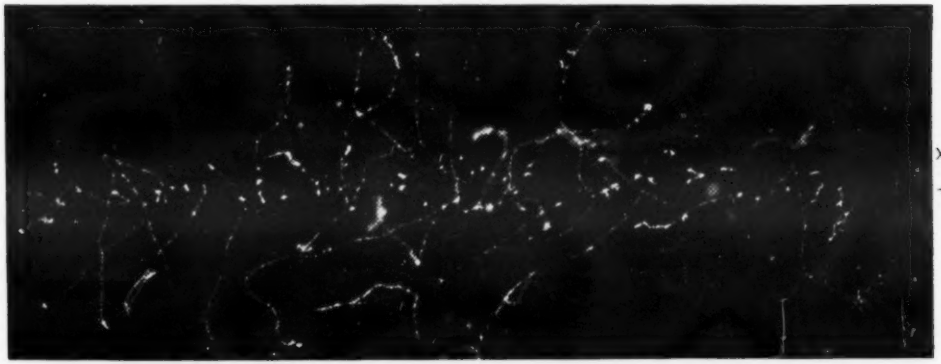
photograph[11] of the collision of an alpha particle with an oxygen atom, the long branch of the fork representing the track of the alpha particle after collision, the shorter branch the track of the struck oxygen nucleus.[12] In figure 4 where the alpha particle (helium nucleus) and the

[11] On one film appear two images of the objects, viewed from directions mutually at right angles.

[12] The second track from the left in the left-hand group, and the fourth from the left in the right-hand group, are the two different views of the same very definite forked track.

PLATE 2

Tracks of Fast and Slow Beta Rays, Produced by X-Rays, "Cloud Method"
(C. T. R. Wilson). Courtesy Proceedings Royal Society



Different Classes of Beta Ray Tracks Produced by Hard X-Rays, "Cloud Method"
(C. T. R. Wilson). Courtesy Proceedings Royal Society

struck helium nucleus are of equal mass, the close impact of the nuclei has been proved according to the ordinary laws of mechanics.[13]

In the case of all atoms, it must be noticed that the mass of the nucleus is, for all practical purposes, the mass of the atom. The individual electrons are too light to affect appreciably the total mass of the atom. The fundamental question which next confronted the physicists was: What is the magnitude of the positive charge of the nucleus? This amounts to determining the number of electrons surrounding the nucleus in the normal neutral state of the atom; since the number of electrons (negative) which circulate about the nucleus

Fig. 3

Fig. 4

Fig. 3. Forked alpha ray track, showing collision with oxygen atom. Double photograph (P. M. S. Blackett). Courtesy Proceedings Royal Society.

Fig. 4. Forked alpha ray track, showing collision with helium atom. Double photograph (P. M. S. Blackett). Courtesy Proceedings Royal Society.

(positive) must, to preserve the neutral state of the atom, be equal to the number of net positive charges in the nucleus.[14] At first Ruther-

[13] By the theory for the collision of two elastic spheres of equal mass, the paths of the two after collision should be at right angles to each other. Computation gave the angle between them to be 89° 45′—an extraordinary verification.

[14] If the fundamental quantum of negative electricity, 4.77×10^{-10} electrostatic units be termed the "unit charge," then the nuclear charge must be a whole number.

ford was inclined to believe that the nuclear charge was half the atomic weight, from observations on alpha particles. He showed that a helium *atom*, when expelled as an alpha particle, carries a positive charge of two units; and since there is every reason to believe that an alpha particle is a helium *nucleus* deprived of its electrons, it follows that the electronic system of the neutral helium atom consists of two electrons.[15] This "law" was found to be only an approximation; and was soon displaced by the brilliant idea advanced (1913) by a Dutch physicist, van der Broek, that the number of electrons in the atom of an element is equal to its "atomic number." By a study of X-ray spectra, Moseley demonstrated that *the atomic number of an element is a measure of its nuclear charge*. This discovery was of fundamental importance, since it not only fixes the number of electrons in all the atoms, but shows conclusively that the properties of an atom are

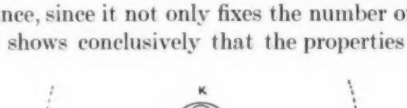


Fig. 5. Conjectured structure of the helium atom. *K*, nucleus system with four hydrogen nuclei and two nuclear electrons; *E*, electrons in the outer electron system.

determined, not by its atomic weight, but by its nuclear charge. In the case of helium, for example (fig. 5), with atomic weight 4, atomic number and nuclear charge 2, the nucleus should consist of four hydrogen nuclei (since the electrons virtually do not affect the mass or weight); and since these represent 4 positive charges, there must also be present in the nucleus 2 (negative) electrons, in order to make the resultant nuclear charge equal to 2.[16] While some authorities are opposed, it is pretty generally believed that the helium atom can be formed from hydrogen nuclei, although no experimental proof of it has yet been given. The enormous energy developed by the alpha rays, the most powerful bombarding weapon yet discovered, is quite insufficient to disintegrate the exceedingly stable helium atom. Experiments conducted by

[15] Thus 2, the number of electrons, is one-half the atomic weight of helium, which is 4.

[16] To take a more complicated case, consider Radium *C*, atomic weight 214, atomic number 83. In this case the nucleus must contain 53 helium nuclei (each containing 4 hydrogen nuclei) and 2 hydrogen nuclei (total, $4 \times 53 + 2 = 214$), all positive, and 131 electrons ($214 - 83$).

Rutherford and Chadwick suggest, according to the former, "that the hydrogen nucleus or proton must be one of the fundamental units which build a nucleus, and it seems highly probable that the helium nucleus is a secondary building unit composed of the very close union of four protons, and two electrons."

It can now be seen how the nuclear theory of the atom offers a simple interpretation of the relation between isotopic elements. Since the chemical properties of an element are controlled by its nuclear charge and little influenced by its mass, isotopes must correspond to atoms with the same nuclear charge but of different nuclear mass. Moreover, we see now why argon and potassium, for example, having atomic weights 39.88, 39.10, have atomic numbers 18,19; the inversion in the natural order of increasing atomic weights is caused by the fact that the nucleus of potassium contains one more unit of charge. Further, the Theory of Relativity helps us to understand why the atomic weight of hydrogen is 1.008, instead of 1, as we should expect. According to Einstein, mass is a function of energy; and when a small amount of mass is lost, an enormous amount of energy is dissipated. If four hydrogen nuclei and two electrons come together in close combination to form a helium nucleus, an enormous amount of energy has been expended, with a corresponding but small loss in mass. This follows from the Relativity formula that the loss in mass equals the loss in energy divided by one-half the square of the velocity of light. When the loss of mass is known, the loss of energy is got by multiplying this loss of mass by one-half the square of the velocity of light. Sommerfeld has calculated this to be ten million times greater than amounts in chemical combinations (combustion, etc.). Hence it is, no doubt, that the mass of the helium nucleus comes out 4 in terms of oxygen = 16, instead of 4.03 (4×1.008) as we naturally expect. That the energy set free in forming one gramme of helium is enormous is shown by calculation; for the energy released in the formation of one pound of helium gas is computed to be equivalent to the energy emitted in the complete combustion of about eight thousand tons of pure carbon. Thus it will be seen that the atomic number has acquired a profound physical significance. A spectacular proof of the power of Moseley's law in fixing the atomic number of an element is exhibited in the recent discovery by Coster and Hevesy in Copenhagen of the missing element of atomic number 72.[17]

[17] This element was named by the discoverers hafnium (Hafnia = Copenhagen).

V

The division of the atom into the nucleus and surrounding electrons, and the determination of the number of electrons in the atoms of the various elements, cleared the way for attacking the two problems which naturally suggested themselves.

1. The nature of the arrangement of the outer or "free" electrons, which determines the main physical and chemical properties of an element.
2. The structure of the nucleus, on which the mass and radio-activity of the atom.

We know that when a gas is made to glow, the spectroscope shows that it emits light of two sorts, one of which gives what is known as a "line-spectrum." This spectrum consists of a number of sharp lines of single colors; and each of these lines represents a definite and characteristic mode of vibration of the atom. In his address on "Atoms and Molecules" (1873), Clerk Maxwell announced that every atom of an element, whether in the earth or in a star, vibrates in identical fashion under the same physical conditions. How was it possible, then, to reconcile the extreme simplicity of the hydrogen atom which, on the nuclear theory, consists of a single charged positive nucleus and only one attendant electron, with the complicated optical spectrum? It is clear that the complexity of the spectrum must be ascribed, not to the complexity of the structure of the hydrogen atom, which is exceedingly simple, but to the complexity of the laws of radiation. The subsequent historical development amply confirms the prophecy of the spectroscopists that the key to atomic structure would prove to be the spectrum.

As early as 1900, Planck enunciated the conclusion that atoms radiate energy discontinuously in units equal to, or multiples of, $h\nu$, in which ν is the natural frequency of the radiator, and h an universal constant.[18] In 1905, Einstein assumed that a given source could emit and absorb radiant energy only in units which are all exactly equal to $h\nu$, ν being the natural frequency of the emitter and h a constant which is the same for all emitters. In 1913, Bohr assumed an equation precisely the reverse of Einstein's, embodying the conclusion that the

[18] If a body goes through its whole period (such as the swing of a pendulum) ν times in a second, it is said to have a "frequency" ν. The universal constant h, called Planck's constant, is 6.54×10^{-27}. This quantity is so small that a billion billion times h (where a billion here means a million million, contrary to the sense in which I have used it elsewhere) would be a quantity just appreciable without instruments of precision.

energy lost when an electron jumps from one stationary orbit to another is wholly transformed into monochromatic radiation whose frequency is determined by equating the loss of energy to $h\nu$. It is well to note, as Millikan points out, that "Einstein and Bohr have set up a reciprocal and reversible relation between electronic and radiant energy."

By resorting to conclusions based upon the Quantum Theory, which had been put forward by Planck in 1900, Bohr (1913) enunciated a theory upon which all subsequent investigations of the dynamic-model atom fundamentally rest. On Planck's theory radiation is emitted in *definite units* or "quanta," in which the energy of radiation, E, is equal to $h\nu$, where ν is the frequency of the radiation measured by the ordinary methods, and h is a universal constant. If the energy is

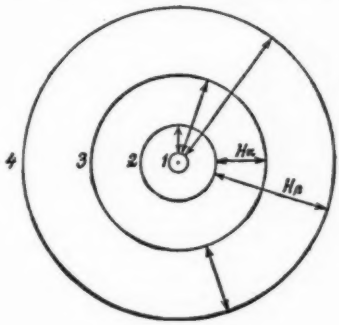


Fig. 6

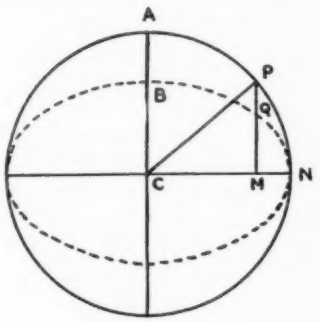


Fig. 7

Fig. 6. The *Bohr* model of the hydrogen atom in the original (simplified) form (circular orbits for the electrons).

Fig. 7. Circle and ellipse.

greater than $h\nu$, it must be exactly twice as great, or three times as great, or etc. In this sense energy itself might be regarded as atomic.[19] Bohr assumed, in the case of the hydrogen atom, that the single electron could revolve in a number of stable circular orbits, controlled by the attractive force of the nucleus, without losing energy by radiation (fig. 6). If however, for some reason, the electron is transferred from one orbit to another, the radiation given out due to change of energy is given by the quantum relation $E \times h\nu$, where ν, is the fre-

[19] It can no longer be strictly maintained that the Quantum Theory, in its present generalized form, involves indivisible parcels or quanta of energy. For our present purpose, however, the above is sufficiently accurate.

quency of radiation and E the difference of energy of the electron in the two orbits. If the radius of the inner orbit is a_1, then the radii of successive orbits are 2^2a_1, 3^2a_1, ... n^2a_1. Here n is called the quantum number; and we have to do with a single series of stationary orbits, each characterized by its quantum number. The formula for the radius of the inner orbit gives the value $a_1 \times 0.532 \times 10^{-8}$ centimeters,[20] and the next successive orbits have radii: 2.128×10^{-8}, 4.788×10^{-8} etc., centimeters. The second orbit is 16 times as large in area as the first, the third 81 times as large in area as the first, and so on. If, for example, the electron is transferred from the second to the first orbit, the loss of energy is $\frac{3}{4}\,\epsilon$, where ϵ is the kinetic energy in the smallest orbit;[21] and hence we have $\frac{3}{4}\,\epsilon = h\nu$. Here the electric force attracting the electron to the nucleus will do work, partly exercised in increasing the kinetic energy of the electron, making its velocity greater in the inner orbit, and partly transformed into radiation energy which is emitted from the atom in the form of monochromatic light. One sensational result of Bohr's theory was the very close agreement it gave with a certain universal constant, known as Rydberg's constant—a circumstance which gave very strong support to the theory.

By elaborate investigations, Sommerfeld subsequently showed that the electron may also revolve in elliptic orbits around the hydrogen nucleus as a focus.[22] The energy for the elliptic orbits is found to be the same as that for the respective circular orbits, on replacing the quantum number n by the quantum sum $n+ n^1$, where n and n^1 are both whole numbers, and n^1 is less than or at most equal to n. Also it is found that $(a - b)/b = n^1/n$, where a and b are the semi-major and semi-minor axes, respectively, of the ellipse.[23] In the case of the ellipse (fig. 7), where $CN = CA = a$ (equal radii of same circle),

[20] From this formula, $a_1 = h^2/ 4\pi^2me^2$, we see that the diameter of the hydrogen atom in its "normal state" is of the order of magnitude 10^{-8} centimeters, corresponding to the results obtained for the size of molecules from the theory of gases. A molecule of hydrogen is equal to 2 atoms.

[21] The kinetic energies in the respective orbits, as a simple calculation shows, are ϵ, $\frac{1}{4}\epsilon$, $\frac{1}{9}\epsilon$, etc.

[22] An ellipse is an oval curve (fig. 7, dotted curve), and may readily be drawn as follows: tie a piece of thread to two pins stuck vertically into a sheet of paper lying horizontally, so that the string hangs loose; and by moving a pencil point around inside the string pulled taut, you will describe an ellipse. Each of the pin pricks is a focus of the ellipse. In figure 6, the common center of all the circles is the (left-hand) focus of each of the six ellipses (ovals), 2_1, 3_2, 3_1, 4_3, 4_2, 4_1.

[23] In figure 7, $CN = a$, $CB = b$, where CN, CB are the semi-major, semi-minor axes, respectively, of the ellipse.

$CB = b$, the last equation means: AB:BC = n^1:n. If we diminish all the vertical lines on the circle, such as MP, in the same ratio, say $n^1 : n$, we will have the dotted curve which (by this very construction) is an ellipse. Our problem then is to arrange our orbits according to the sum $n + n^1$. Thus we form the table below. In this table, we note that n is never zero, since this would require the electron to fall into the nucleus, which is impossible owing to the permanence of atoms. Here $n + n^1$ is called the total quantum number and n the auxiliary quantum number; and each orbit is designated by these two numbers, as in the figure (fig. 8): 4_4, 4_3, 4_2, 4_1, 3_3, 3_2, 3_1, 2_2, 2_1, 1_1. The circles and ellipses are drawn to scale, according to the table. Of course $n + n^1$ continues to increase indefinitely, one unit at a time; but only four sets of orbits are shown in the figure.

$n + n^1$	n	n^1	a	b	e	Orbit
1	1	0	a_1	a_1	0	Circle
2	2	0	2^2a_1	a	0	Circle
	1	1	2^2a_1	$a\sqrt{2}$	$\sqrt{3/2}$	Ellipse
	3	0	3^2a_1	a	0	Circle
3	2	1	3^2a_1	$\frac{2}{3}a$	$\sqrt{5/3}$	Ellipse
	1	2	3^2a_1	$\frac{1}{3}a$	$\sqrt{8/3}$	Ellipse
	4	0	4^2a_1	a	0	Circle
4	3	1	4^2a_1	$\frac{3}{4}a$	$\sqrt{7/4}$	Ellipse
	2	2	4^2a_1	$\frac{2}{4}a$	$\sqrt{12/4}$	Ellipse
	1	3	4^2a_1	$\frac{1}{4}a$	$\sqrt{15/4}$	Ellipse

There are convincing reasons for choosing these as the possible orbits of the electron in the hydrogen atom, instead of only circular orbits as in the original Bohr model (1913).[24] In fact, the elliptical orbits, as circular orbits do not, explain the Zeeman effect, which shows how magnetism splits one line into three or more; the Stark effect, which shows the influence of an electric field; and finally the phenomenon known as "fine structure." This last is so significant as to deserve a more explicit statement.

According to the General Relativity Theory, Einstein showed that as the planet Mercury moved in its elliptical orbit, the orbit itself as a whole revolved; and that the advance of the perihelion point (the point

[24] In 1919, Bohr stated: "The original assumption that the electrons in the normal state of the atom move in specially simple geometrical orbits, *e.g.*, rings of electrons, can no longer be maintained."

of the ellipse nearest the focus) was 43 seconds of arc per century. A somewhat similar phenomenon occurs with the electron, on invoking the Special (not the General) Relativity Theory. As early as 1881, J. J. Thomson showed that a charged body in motion behaves as if it had an additional mass due to its motion; and in 1902 Kaufmann, by experiments on swift electrons ejected from radium, showed that the mass of the electron increased rapidly as the velocity of the electron

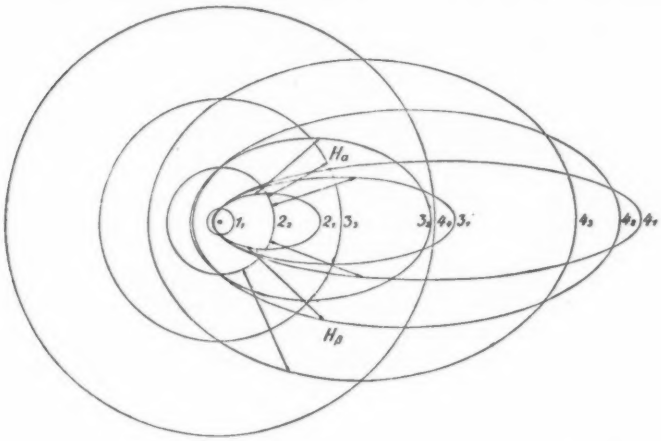


Fig. 8. The model of the hydrogen atom with stationary orbit corresponding to total quantum numbers and auxiliary quantum numbers (Sommerfeld).

approached that of light.[25] By the Special Relativity Theory, Einstein showed that for any material particle, whether charged or not, the mass increases with the velocity according to a definite ratio.[26] The law of attraction existing between the nucleus and the electron is that of *electric charges*, not of masses; and if the charges remain unchanged, while the mass of the electron varies, the motion will be changed, because the same force has less effect upon a greater mass. Hence, applying the Einstein formula for change of mass with velocity, we shall

[25] When the electron reaches 0.99 times the velocity of light, its mass is increased eight-fold.

[26] Einstein's formula is $m = m_0 (1 - v^2/c^2) - \frac{1}{2}$, where m_0 is the mass for low speeds, v is the velocity of the particle, and c is the velocity of light, viz. 3×10^{-10} centimeters, or a billion feet, per second.

obtain as orbit a Kepler ellipse which slowly rotates in the plane of the orbit (fig. 9). The figure should show (if that were possible) 40,000 loops around the nucleus (focus) for one complete rotation of the major-axis through four right angles, since the electron revolves about 40,000 times around the nucleus while the major-axis turns around once.

Now the hydrogen lines possess what is called a "fine structure": with spectroscopic apparatus of high resolving power each line in the spectrum can be separated into two lying very close together. The transition 3 − 2, for example, which in the case of circular orbits only was represented by a single line in the spectrum, is replaced by several

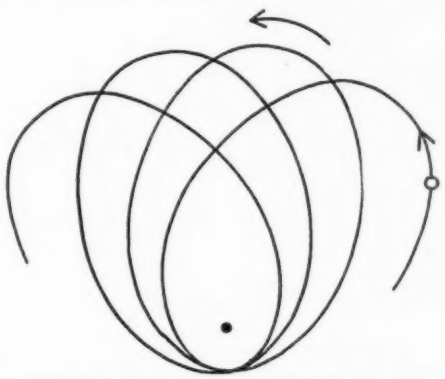


Fig. 9. A compound electron motion produced by the extremely rapid rotation of an elliptical orbit about the nucleus, according to Einstein's Special Relativity Theory.

transitions $3_3 - 2_2$, $3_2 - 2_1$, etc. which are represented by several spectral lines lying close together (fig. 8). The energy content of the atom is almost the same for orbits with the same total quantum number and different auxiliary quantum numbers; and hence three transitions like $3_3 - 2_2$, $3_2 - 2_1$, and $3_1 - 2_2$ will give about the same frequency, and therefore spectral lines which lie very close together.

VI

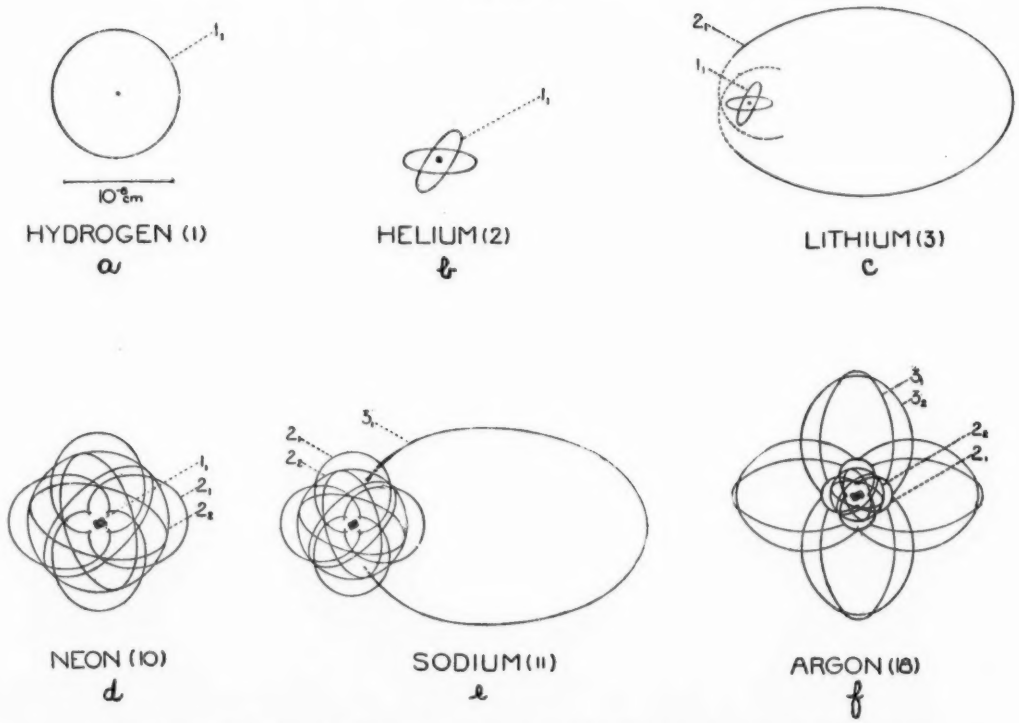
The brilliant recent work of Bohr in determining the distribution of the electrons around the nucleus of any atom in its most stable state has attracted international attention, of the type focussed by Einstein with his Theory of Relativity. For heavy atoms, the problem of determining

the distribution of the free electrons is far more complicated than in the case of the hydrogen atom with its single electronic satellite. In the heavier atoms, the orbit of certain free electrons is found to be, not a Kepler ellipse, but a curve consisting of a series of elliptical loops. Each of the large number of electrons present acts upon the others; and where a "comet" electron dives into the inner structure of the atom, it moves rapidly around the nucleus, towards which it approaches even closer than some of the innermost groups of electrons. In his effort to solve the complex problems involved, Bohr sought to discover how a normal (neutral) atom may gradually be formed by the successive capturing and binding of the individual electrons in the field of force about the nucleus of the atom.

If the nucleus is a *hydrogen* nucleus, the hydrogen atom is completed when the electron has come into the 1_1 orbit, a circle with diameter of about 10^{-8} centimeters or one three hundred millionth of an inch (plate 3, a). In this innermost orbit the electron revolves with the velocity of about 1400 miles per second, or one hundred and thirty-fourth the velocity of light. It thus goes around its tiny orbit about seven thousand million times in a millionth of a second. In the *helium* atom, the first electron captured by the nucleus of positive charge 2 revolves in a circle 1_1, with a radius half that described in the hydrogen atom.[27] The next electron captured moves in another circular 1-quantum orbit of the same size, making with the plane of the orbit of the first electron an angle of 135° (plate 3, b). This group of two electrons, known as the K group, is common to all atomic nuclei of higher charges than the helium nucleus (plate 3, c, d, e, f, plate 4). In the *lithium* atom (nuclear charge 3), there is captured a third electron, which moves in a 2-quantum orbit consisting of oblong loops (plate 3, c). Passing over the intervening elements, let us now consider *neon* (10), the next inert gas. The *neon* atom has a particularly stable structure, having besides the K group (2 electrons) four electrons in 2_1 orbits and four electrons in 2_2 orbits (plate 3, d). This new group of eight electrons, called the L group, appears in all atoms of higher atomic number than neon (plate 3, e, f); and as in the case of the K group, the speed of motion of the electrons increases, and the size of their orbits diminishes proportionately with increasing atomic number. When we pass to

[27] The radius of the orbit of the inner electron varies inversely as the nuclear charge. As the nuclear charge increases, the innermost electrons which move in 1-quantum orbits move with increasing speed, and approach closer to the nucleus.

PLATE 3



Main lines of the atomic structure of hydrogen, helium, lithium, neon, sodium and argon.
(After Kramer and Holtz.)

sodium (11), the new (eleventh) electron which is captured, since it cannot interfere with the stable *K* and *L* groups, must move in another (*a* 3_1) orbit (plate 3, e). As we pass up the scale of atomic numbers, we get two 3_1 orbits in *magnesium* (12), a 3_2 orbit is for the first time added in *aluminium* (13); and so we finally reach *argon* (18) of symmetric architecture, with eight 3-quantum orbits besides the *K* and *L* groups (plate 3, f).[28]

This building process has been carried out by Bohr with extraordinary ingenuity. As soon as the L group has been completed a still more complicated, M group begins forming outside it, and a similar process continues until *uranium* (92), with highest atomic number, is reached.

TABLE II

Table showing the distribution of the electrons of different orbital types in the neutral atoms of the inactive gases

	ATOMIC NUMBER	QUANTUM NUMBERS																						
		1_1	2_1	2_2	3_1	3_2	3_3	4_1	4_2	4_3	4_4	5_1	5_2	5_3	5_4	5_5	6_1	6_2	6_3	6_4	6_5	6_6	7_1	7_2	7_3
Helium.....	2	2																						
Neon.....	10	2	4	4																				
Argon.....	18	2	4	4	4	4	–																	
Krypton.....	36	2	4	4	6	6	6	4	4	–	–													
Xenon.....	54	2	4	4	6	6	6	6	6	6	–	4	4	–	–	–								
Niton.....	86	2	4	4	6	6	6	8	8	8	8	6	6	6	–	–	4	4	–	–	–	–		

A glance at the table for the inactive gases (table II) clearly indicates the mode of successive formation of the atomic structure. On grounds of stability—for the fact must be kept in mind that the electronic system does not more frequently break down—Bohr holds that the more eccentric orbits are filled first, and the less eccentric ones later. The *radium* atom (88) furnishes an instructive case for study. Besides the K and L groups (10 electrons), it has 18 electrons in 3-quantum orbits, 32 in 4-quantum orbits, 18 in 5-quantum orbits, 8 in 6-quantum orbits,[29] and finally 2 in 7-quantum orbits (plate 4). It is to be observed that the electrons of one group may penetrate deeply into the region mainly

[28] From spectroscopic considerations, reinforced by those of stability, Bohr concludes that none of these eight outer electrons moves in a circle.

[29] Of these 8, 4 move in very eccentric orbits, the other 4 in less eccentric orbits. The last two electrons are called "valence electrons," which easily get loose and leave behind a positive radium ion with stable niton architecture (table II).

occupied by another group, thus giving a type of interlocking between the various groups. Concerning the speed of the electrons in their respective orbits, take *uranium* (92) as an illustration. The outermost electron will have a minimum speed of more than a thousand kilometers per second, while the innermost K electrons have an average speed of more than 150,000 kilometers per second, or half the speed of light.

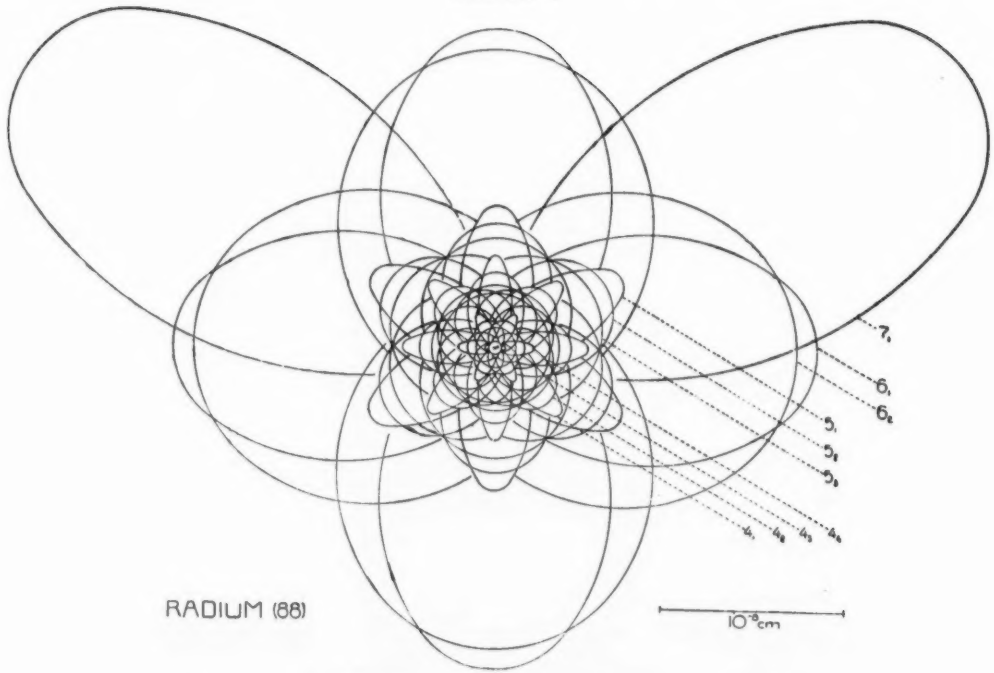
VII

The discovery of X-rays by Roentgen in 1895 quickly led to elaborate study of the X-ray spectra of the elements. When "cathode rays" (a stream of alpha particles) or beta rays strike a substance, they give rise to X-rays which vibrate transversely like light. The discrete lines in the X-ray spectra correspond to frequencies of vibration in the atom; and experiment shows that the X-ray spectra are connected with disturbances in the inner rings of electrons. The frequency of each line (K, L or M) in the X-ray spectra increases very rapidly as we go through the table of the elements, viz. approximately as the square of the atomic numbers. The K line represents a transition by an outer electron to the inmost ring, the L line represents a transition to the second ring, and the M line to the third. An electron in the cathode stream, on reaching the inner ring of electrons, ejects one of the electrons with enormous force; and the ejected electron passes completely out of the atom, being repelled by the electrons in the outer rings. To preserve stability, an electron from the outer rings drops into the inner ring to fill the place of the ejected electron. The atom thus loses energy, which spreads out in a wave just like a light wave. The outer ring eventually picks up another electron, either from another atom or a free electron, to replace the one it has lost. From the frequencies of the different lines in the X-ray spectra, we can infer what are the differences between the energies of electrons in different rings. The X-ray spectra strongly confirm the Bohr-Rutherford dynamic theory of atomic structure.

VIII

The present age may well be called the Golden Age of scientific research. Indeed the past quarter of a century has been called the Renaissance of Physics. While the static models of the atom, upon which many investigators are at work, have proven of great value in chemistry, the triumph of the dynamic model in the field of physics at the present time appears complete. Planck with the Quantum Theory

PLATE 4



STRUCTURE OF THE RADIUM ATOM
(After Kramers and Holst)

and Einstein with the Relativity Theory have furnished solid foundations upon which the structure of the Bohr-Rutherford dynamic model rests. The striking quantitative triumphs of the dynamic model have, however, been largely restricted to the case of one moving electron; and the suggested structure of the heavier atoms is as yet largely speculative, although there is the highest probability that the models give us a more or less correct general picture of the behavior of the electrons. Certain fundamental assumptions made by Bohr are in direct contradiction to the hitherto accepted "laws" of electro-dynamics; and many riddles evoked by his theory yet remain unsolved. The study of the nucleus, that atom within the atom, is as yet in its infancy. It seems certain that the law of inverse squares breaks down inside the nucleus; and no material progress in the study of the detailed structure of the nucleus can be made until the nature and law of variation of the forces inside the nucleus are determined. The problem of the twentieth century physicist is the synthesis of the universe. To paraphrase Archimedes, he may well say: "Give me the atom, and I will build the world."

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In addition to the above, many periodical publications, by F. W. Aston, J. Chadwick, Niels Bohr, P. M. S. Blackett, C. T. R. Wilson, F. Soddy, and others, have been consulted. In the preparation of the above paper, I am especially indebted to the writings of Rutherford, Bohr, Millikan, Russell, and Sommerfeld.

SOME UNDESCRIBED FUNGI ON SOURWOOD, OXYDENDRON ARBOREUM (L.) DC.

By FREDERICK A. WOLF

PLATES 5 AND 6

The sourwood, *Oxydendron arboreum* (L.) DC., is of peculiar scientific interest because it is the only member of the heath family which attains the proportions of a tree. In addition, it is of special economic importance throughout the coastal plains section of the Carolinas because it is not excelled as a honey-producing plant. During the past two years, the writer has made, at different points in eastern North Carolina, a number of collections of fungi on this host. Moreover, a survey of mycological literature shows that sourwood is subject to infection by a number of parasitic fungi. It appears from studies made to identify the species of these collections that they include three species which differ from those that have previously been described on sourwood, and other ericaceous hosts. It is the present purpose, therefore, to describe the essential structural and developmental features of these three forms.

Specimens of each species have been made available by deposition in the office of Pathological Collections, Bureau of Plant Industry, Washington, D. C., the herbarium of the New York Botanical Garden, New York, N. Y., and the herbarium of Harvard University, Cambridge, Mass.

Sphaerella caroliniana n. sp.[1]

About the middle of July, reddish to purplish discolorations begin to appear on the foliage of sourwood. These are the primary lesions resulting from ascospore discharge from fallen leaves. The central portions of these lesions soon become dry and brown and shortly afterward black pycnidia are formed, which are embedded within the tissues and protrude from the lower leaf surface. The pycnidia are rather densely grouped (figs. 1 and 10) and range in diameter from 90 to 100μ. The pycnidial wall is composed of a single layer of thick walled, dark brown cells (fig. 5). The conidia are hyaline, oblong, and vary in size from 5–7 x 2–3.5 μ (fig. 6).

[1] The generic name *Sphaerella* is used in the same sense as that employed by Saccardo. Syll. Fung. **22**: 120 (footnote). 1913.

The secondary infections which arise from successive crops of conidia may become so numerous as to involve all of the leaves on all trees in a given locality and cause their premature defoliation. During early September, spermatia are formed in place of conidia, apparently in the pycnidial chambers. The spermatia are 4–5 x 1.5μ and are characteristically enlarged at both ends (fig. 7). Repeated attempts to germinate these spermatia have been fruitless. No particular difficulty has been experienced, however, in securing cultures on agar from conidia.

Mature perithecia are present in abundance on fallen decaying leaves during the last of March (plates 5 and 6). They are grouped as were the pycnidia, are of the same size, and the walls are of similar texture. The asci are fasciculate, clavate, 40–45 x 7–8μ (fig. 3). The ascospores are biseriate, 9–11 x 3–4μ and are unequally two-celled, with the upper cell larger (fig. 4). As an initial step in spore discharge, the outer ascus wall is ruptured at a median point on the lateral wall and the thin inner vesicle elongates, from turgescence (fig. 3) so that the asci reach to the mouth of the ostiolum. The ascospores are then discharged in rapid succession after which the empty ascus is retracted. Advantage has been taken of this phenomenon to secure pure cultures from ascospores by inversion of poured agar plates above leaves bearing mature perithecia. Within fifteen hours (fig. 2) the ascospores will have germinated, usually with the formation of a germ tube from the end of each cell. Four or five days are required for the colonies to be of sufficient size to be visible to the unaided eye. Subsequent growth is slow and small grayish adpressed colonies are formed. They are similar in appearance to those originating from conidia. No evidence of fruiting in culture has been noted, although a variety of media have been employed with strains both from ascospores and from conidia. Proof of the relationship of the pycnidial and ascigerous stages, therefore, rests on the similarity of the colonies in culture and on their association in succession in the same lesions.

The *Phyllosticta* stage of this fungus has been compared with types of *P. oxydendri* E. et E. and *P. vaccinii* Earle, and found to differ in several essential features. When it is compared with the original description of *Sphaerella vaccinii* Cke.[2] and with *S. maculiformis* (Pers.) Awd. it is seen to be wholly unlike either. It is, therefore, given the name *Sphaerella caroliniana* with the following brief Latin diagnosis:

Peritheciis hypophyllis, dense gregariis epidermide velatis, poro

[2] Cooke, M. C. Jour. Bot. 1866, p. 249, pl. 50, fig. 11.

pertusis globulosis, nigris, tenui-membranaceis, 90–120μ diam.; ascis fasciculatis, clavatis, apice, rotundatis, aparaphysatis, octosporis, distichis, 40–45 x 4–8μ; sporidiis hyalinis, leviter curvulis, constrictis, bicellularibus, loculis subaequalibus, cellula superiore paullo latiore, 9–11 x 3–4μ.

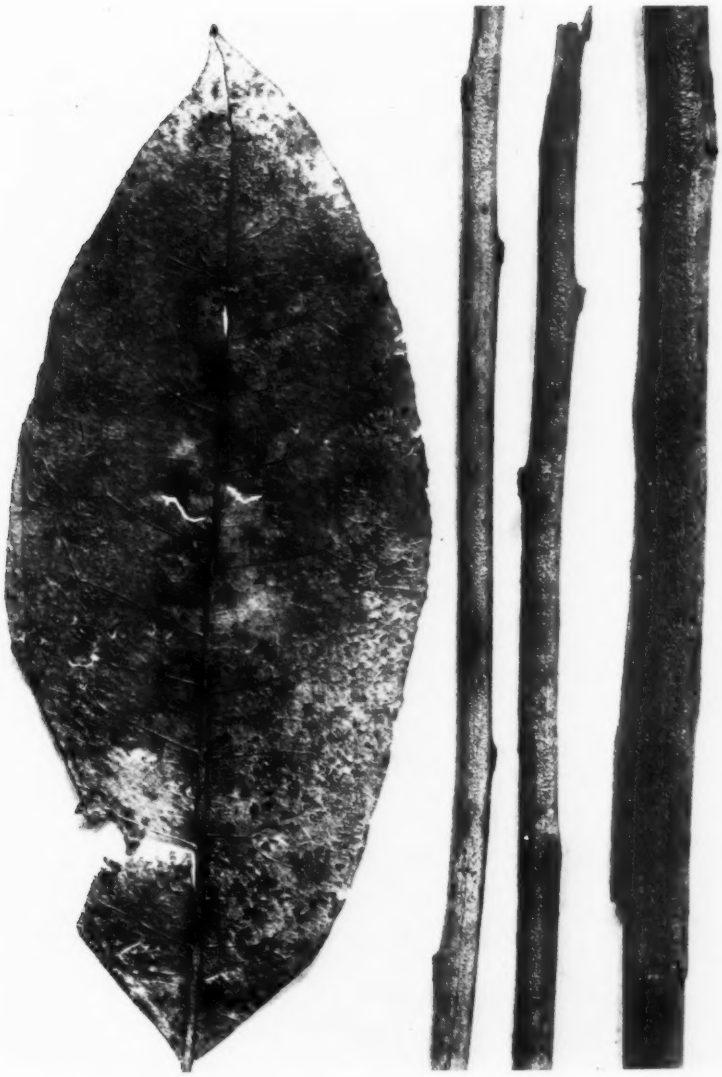
Hab. in foliis dejectis Oxydendri arborei. Status conidicus: maculis arescentibus, indeterminatis; pycnidis hypophyllis, globosis, gregariis, innatis, ostiolatis, atris, 90–100μ diam.; conidiis hyalinis, oblongiis, 5–7 x 2–3.5μ; spermatiis autumno in spermagoniis, 4–5 x 1;5μ utrinque capitibus.

Sphaerulina polyspora n. sp.

This organism produces a "die-back" disease and appears to gain entrance through twigs which are injured by fire or are moribund from other causes. Affected twigs can be recognized by the presence of numerous, black pimple-like prominences (plate 5) which on examination prove to be the pycnidia of a species of *Phoma*. These pycnidia are at first innate but become erumpent at maturity. They average 175μ in diameter and contain ellipsoidal conidia 7–8 x 3,8–4μ. The conidia become considerably swollen on the initiation of germination. A median septum is then formed. Each cell continues to enlarge and a deep constriction is formed at the septum. This is followed by the formation of another septum in each cell so that the whole is four-celled. Each of these cells may then elongate and divide again so that a chain of eight elements is produced. If the divisions in pairs have not been simultaneous from the first the chains are composed of 3, 5, 6 or 7 elements. These chains remain short and tend to fall apart at the deepest constrictions which occur between each pair of cells. Certain of the cells may form short germ tubes instead of dividing or may give rise to an indefinite number of yeast-like buds. Then again, the elements may by division and enlargement give rise to structures which resemble ascospores of the *Sphaerulina* stage. Septa may be formed in two planes in such structures and in this condition they simulate a late stage in the germination of ascospores. Various stages in germination are illustrated in figure 17. The colonies on agar are never myceloid, but wet-shining, and yeast-like in appearance.

In spring, perithecia are abundantly present on twigs which were occupied by the pycnidial stage during the previous autumn. These perithecia vary in diameter from 150–180μ and arise within the cortical parenchyma. The wall consists of a single layer of brown thick-walled cells (fig. 14). The asci remain clustered when the perithecia are crushed in making microscopic mounts. Paraphyses are wanting.

PLATE 5



Groups of perithecia of *Sphaerella caroliniana* on sourwood leaf, and twigs bearing conidial and ascigerous stages of *Sphaerulina polyspora*.

The asci are 90–100 x 18–20μ and contain eight hyaline 3–5 septate, constricted ascospores which measure 20–24 x 6–7μ (fig. 8).

On germination the ascospores enlarge and septations in more than one plane are formed (fig. 16) or yeast-like buds are formed (fig. 12). These buds form secondary buds (fig. 11) so that colonies of yeast-like appearance are developed within 5 to 7 days. Sometimes short hyphae are formed, but the mycelia are never of sufficient length to project from the margin of the colonies. The appearance of these colonies is similar in all respects to those arising from conidia and the relationship of the two stages is based primarily on this fact.

Ordinarily when budding fungi are mentioned, the mycologist thinks of the true yeasts. It is well known, however, that the smuts bud in giving rise to secondary sporidia and that the same phenomenon is exhibited by various genera among the Auriculariales and Tremellales. Among other forms which are known to bud may be mentioned *Microstroma juglandis* var. *robustum*,[3] *Exoascus deformans*,[4] *Nematospora phaseoli*,[5] *Polyspora lini*,[6] *Sphaceloma ampelinum*,[7] *Protocoronospora nigricans*,[8] *Sphaerulina intermixta* and *Plowrightia ribesia*,[9] and *Dematium pullulans*.[10] These examples, which are chosen at random, indicate that budding is not confined to any one order or family of fungi. While the budding habit of *Sphaerulina polyspora* and of these other plants is of especial interest yet it is believed to be without taxonomic value and cannot be regarded as indicative of phylogenetic relationship.

The available literature does not appear to contain a description of a *Sphaerulina* like the one under consideration and it has not been possible to identify it with closely related genera such as *Metasphaeria* where it may have been described. It is, therefore, given the specific name, *polyspora*, because of its peculiar budding habit. A brief Latin summary follows:

Peritheciis in cortice innatis eumque protrudentibus, globosis, atris; 145–180μ, ascis caespitosis, aparaphysatis, ovoideis-cylindraceis, 90–100 x 18–20μ, sporidiis hyalinis, fusoidis, primo continuis, serius 1–3-septatis postremo 5-septatis constrictis, 20–24 x 6–7μ; Pycnidis perithecia omnino imitantibus; conidiis hyalinis, ellipsoideis, 7–8 x 3.8–μ.

Hab. in ramis Oxydendri arborei igne necatis.

[3] Higgins, B. B. Phytopath. **7:** 42–45. 1917.
[4] Mix, A. J. Phytopath. **14:** 217–233. 1924.
[5] Wingard, S. A. Phytopath. **12:** 525–532. 1922.
[6] Lafferty, H. A. Sci. Proc. Royal Dublin Soc. **16:** n. s. 22, 248–274. 1921.
[7] Viala, P. and Pacottet, P. Rev. d. Vitic. **22:** 117–121, 145–150. 1904.
[8] Wolf, F. A. Jour. Elisha Mitchell Sci. Soc. **36:** 72–85. 1920.
[9] Brefeld, O. Untersuch. **10:** Tab. 7 and 9, 1891.
[10] Berlese, A. N. Bull. Soc. Myc. France **11:** 34–74. 1895.

Venturia oxydendri n. sp.

This form occurs on fallen leaves in association with *Sphaerella caroliniana*. The perithecia are widely separated within the tissues and interspersed between groups of closely aggregated perithecia of *S. caroliniana*. They are provided with two to three setae (fig. 15) which arise at the base of the papilla that marks the ostiolum. They have a diameter of 130–150μ. The wall is thin and membranaceous. The asci measure 90–110 x 18–20μ The ascospores are hyaline but very densely granular and vacuolate. They are oblong-ovate in outline, rounded at the upper end and tapered below, and are divided into two unequal cells. The upper cell is approximately four times as long as the lower one (fig. 9). They measure 16–19 x 6.5–7.5μ. The paraphyses are filiform.

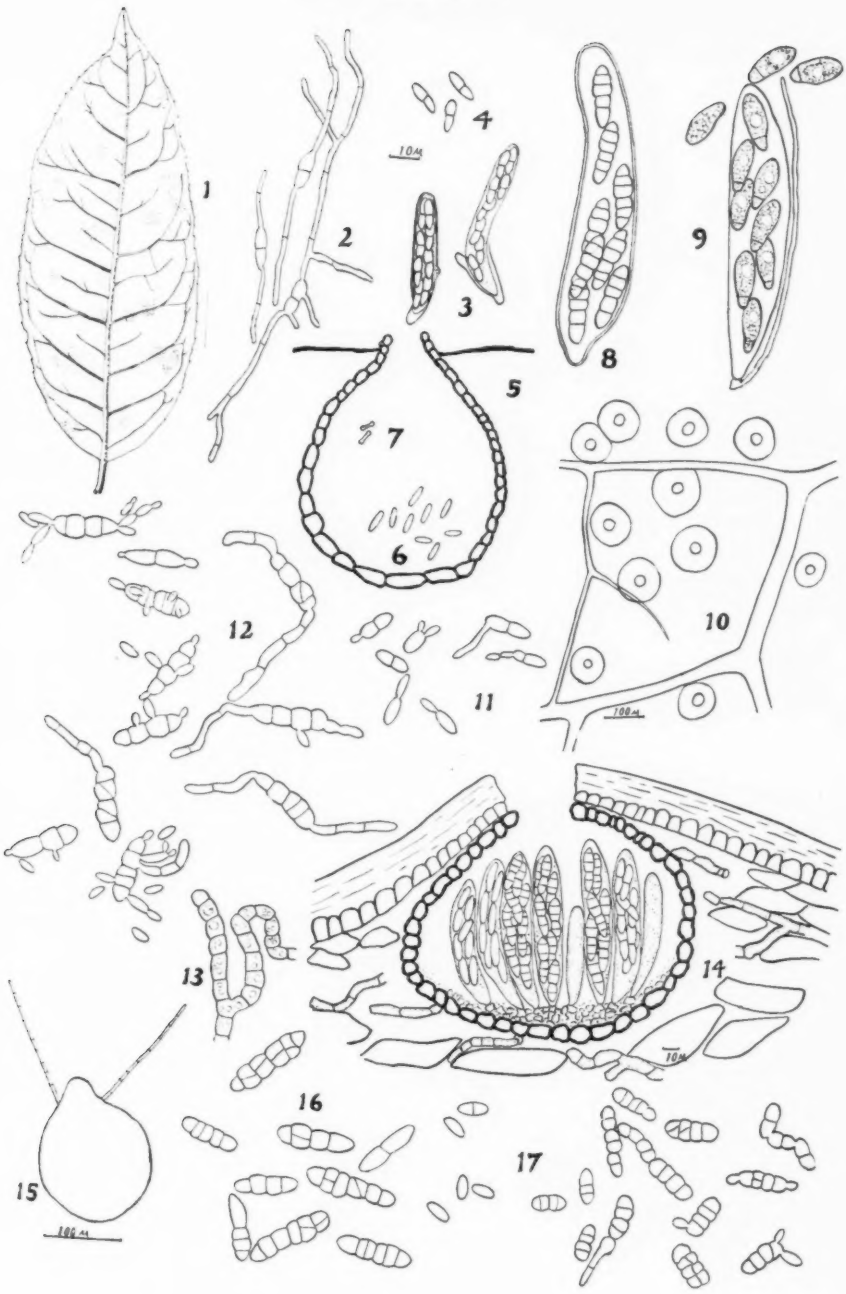
Since a number of species of *Venturia* have been described on ericaceous and vaccineaceous plants an attempt was made to identify the form on *Oxydendron* as one of these plants. When judged by comparison with specimens of *V. atramentaria* Cke., *V. gaultheriae* E. et E., *V. myrtilli* Cke., *V. pezizoidea* Sacc. et Ell., *V. elegantula* Rehm., and *V. petasiditis* (Fkl.) Sacc., it is found to be clearly distinct. Furthermore, its morphological features differ from those given in descriptions of *V. alpina* Sacc., *V. arctostaphyli* Cke., *V. cincinnata* (Fr.) Rostr., *V. compacta* Peck, and *V. vaccinii* E. et E., all of which have been described on closely related hosts. The brief Latin description which follows summarizes the essential morphological features of the *Venturia* under consideration:

Peritheciis sparsis, hypophyllis, innato-erumpentibus, apice papillatis atque setaceis, pyriformibus, atris, 130–150μ diam.; ascis paraphysatis, ovoideo-cylindraceis, 8-sporis, 90–110 x 18–20μ, sporidiis oblongo-ovatis, subinaequilateralibus, utrinque rotundatis, valde inaequaliter bicellularibus, infero minore, plasmate granuloso-farctis, 16–19 x 6.5–7.7μ

Hab. in foliis emortuis Oxydendri arborei.

STATE COLLEGE STATION,
RALEIGH, N. C.

PLATE 6



EXPLANATION OF PLATE 6

Fig. 1. Leaf of sourwood showing distribution of perithecia of *Sphaerella caroliniana.*
Fig. 2. Germination of ascospores of *S. caroliniana.*
Fig. 3. Two mature asci of *S. caroliniana,* one of which has burst the outer envelope and elongated preparatory to spore ejection.
Fig. 4. Ascospores of *S. caroliniana.*
Fig. 5. Pycnidium of *S. caroliniana* showing size, character of wall and protrusion of ostiolum.
Fig. 6. Conidia of *S. caroliniana.*
Fig. 7. Spermatia of *S. caroliniana.*
Fig. 8. Ascus of *Sphaerulina polyspora.*
Fig. 9. Ascus and paraphysis of *Venturia oxydendri.*
Fig. 10. The distribution of perithecia of *Sphaerella caroliniana* within areolae of leaf.
Fig. 11. Growth of secondary conidia of *Sphaerulina polyspora* which have budded from ascospores.
Fig. 12. Various types of germination of ascospores of *Sphaerulina polyspora.*
Fig. 13. Closely septate mycelium of *S. polyspora* from tissue of twig.
Fig. 14. Section of perithecium of S. *polyspora.*
Fig. 15. Diagram in outline of perithecium of *Venturia oxydendri.*
Fig. 16. Ascospores of *Sphaerulina polyspora* in initial stages of germination.
Fig. 17. Stages in germination of *Phoma* stage of *S. polyspora.*

Figs. 2–9 inclusive, 11–13, and 16 and 17 are drawn to the same scale; figs. 10, 14 and 15 have magnifications indicated near each figure.

THE SEASONAL CATCH OF SNAKES AT RALEIGH, N. C.

By C. S. Brimley

In looking over L. M. Klauber's "Notes on the Distribution of Snakes in San Diego County, California" (Bulletin of the Zoological Society of San Diego, No. 1, June 1, 1924), I noticed that his seasonal catch for 1923, the only year for which figures were given, started with 8 in January, increased rapidly month by month till the high point of 129 was reached in May, and then fell rapidly again until November had only 2 recorded captures and December none at all.

This led me to wonder how our Raleigh catch would compare and so I got together all my records and tabulated them month by month but with quite different results from the California data.

Of course his results were of a single year only and yet his total captures recorded was more than half my total which included more or less complete records from the year 1890 to the present time.

My records of captures start with 17 in January, rise more slowly than his to 130 in May, drop gradually to only 27 in September, then take an abrupt rise to 94 in October, and finally drop to only 8 in December.

Next I tried segregating my captures by groups, grouping the different species by their habits as follows: (1) The water and garter snakes which prefer the neighborhood of water, (2) The small burrowing snakes, including not only those allied to the water snakes but also those of the genera *Carphophis*, *Diadophis* and *Tantilla*, (3) The larger terrestrial snakes, mainly of a more or less constricting habit, but including also the genera *Heterodon*, *Cyclophis* and *Cemophora*, and finally (4) The copperhead, which being nocturnal could hardly be placed in any of the other groups.

Group I, including those snakes that prefer the neighborhood of water, reaches its maximum in April, drops off again to September and reaches a secondary maximum in November, which is however less than one third of the spring numbers.

Group II, comprising the small burrowing snakes, also has its spring maximum in April, drops off till September, and abruptly rises to a secondary maximum in October, nearly reaching its spring peak of abundance again.

Group III, the large terrestrial snakes, reach their maximum in May, a month later than groups I and II, and the May catch so much exceeds

TABLE I

Seasonal Catch of Snakes at Raleigh, N. C., by actual numbers recorded

	MONTH												TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	
I. Garter and Water Snakes													
Garter Snake (*Thamnophis sirtalis*)	4	1	7	8	3	8	4	2	0	2	4	0	43
Ribbon Snake (*Thamnophis sauritus*)	3	5	10	20	12	7	1	3	1	3	2	1	68
Queen Snake (*Natrix septemvittata*)	0	0	2	0	0	0	3	2	0	0	2	0	9
Common Water Snake (*Natrix sipedon sipedon*)	0	3	0	7	7	2	1	0	2	2	3	0	27
Southern Water Snake (*Natrix sipedon fasciata*)	0	0	0	0	0	1	0	0	1	0	0	0	2
Copperbelly (*Natrix sipedon erythrogastra*)	0	0	0	1	1	0	0	0	0	1	0	0	3
Totals Group I	7	9	19	36	23	18	9	7	4	8	11	1	152
II. Small Burrowing and Ground Snakes													
DeKay's Snake (*Storeria dekayi*)	3	2	8	10	9	6	2	1	0	5	5	1	52
Red-bellied Snake (*Storeria occipitomaculata*)	0	1	0	7	1	0	2	0	1	2	2	1	17
Ground Snake (*Potamophis striatulus*)	2	3	2	7	4	2	5	1	1	1	6	0	34
Valeria's Snake (*Virginia valeriae*)	0	0	1	7	5	2	2	1	0	10	2	0	30
Worm Snake (*Carphophis amoenus*)	2	1	13	16	11	4	2	3	1	9	7	1	70
Ring-necked Snake (*Diadophis punctatus*)	0	0	1	7	8	6	2	1	2	12	2	0	41
Crowned Tantilla (*Tantilla coronata*)	0	0	0	0	1	0	0	0	0	1	0	0	2
Totals Group II	7	7	25	54	39	20	15	7	5	40	24	3	246
III. Terrestrial Snakes													
Chicken Snake (*Elaphe obsoleta*)	0	0	1	2	10	8	4	0	2	3	1	1	32
Corn Snake (*Elaphe guttata*)	0	0	0	1	2	0	0	0	0	2	0	0	5
Black Snake (*Coluber constrictor*)	0	0	1	6	5	3	3	1	4	2	0	0	25
King Snake (*Lampropeltis getulus*)	0	0	1	7	17	8	4	2	1	4	4	0	48
Brown King Snake (*Lamp. rhombomaculatus*)	0	3	1	2	10	7	4	2	3	4	4	0	40

TABLE I—*Continued*

	MONTH												TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	
III. Terrestrial Snakes—Continued													
Red King Snake (*Lamp. elapsoides*)	0	1	0	5	4	5	3	1	0	3	1	0	23
Green Snake (*Opheodrys aestivus*)	2	0	1	0	0	4	3	3	1	7	3	1	25
Spreading Adder (*Heterodon contortrix*)	1	0	2	1	12	6	3	6	1	8	4	0	44
Southern Hog-nosed Snake (*Heterodon simus*)	0	0	0	0	0	0	0	0	0	2	0	0	2
Scarlet Snake (*Cemophora coccinea*)	0	0	0	1	2	4	0	0	1	0	0	0	8
Totals Group III	3	4	7	25	62	45	24	15	13	35	17	2	252
IV. Pit Vipers													
Copperhead (*Agkistrodon mokasen*)	0	0	0	3	6	11	10	10	5	11	3	2	61
Cottonmouth (*Agkistrodon piscivorus*)	(one undated record before 1890)												1
Grand Total all snakes	17	20	51	118	130	94	58	39	27	94	55	8	711

the April one that the excess makes the former month the month of maximum catch for all snakes combined, this group also has a low mark in September with a secondary rise in October.

Group IV, comprising practically only the copperhead, as our only record of the cottonmouth occurred before I kept dated records, differs from that of all the others in showing a practically even maximum for the months of June, July, August and again in October, with the usual drop in September.

Considering that snakes are warm weather creatures the question naturally arises why the maximum catch should be in the relatively cooler months of April, May and October, the answer appears to lie in the facts that follow,—(1) That the burrowing snakes are not especially hot weather animals; (2) That some snakes at least appear to be more or less nocturnal in very hot weather; (3) That the increased amount of vegetation in summer makes them harder to find and still harder to secure; (4) That a good many of my records come from snakes plowed up in spring; (5) That the snakes' captors are themselves less active in hot weather.

Few of these reasons account however for the marked drop in the catch of all snakes in September and the abrupt rise in October. As I cannot satisfactorily account for these latter facts except partially on the basis of reason No. 5, I will here let the matter rest.

A few other points are of interest, first that only two species are recorded in all the twelve months of the year, these being the ribbon snake (*Thamnophis sauritus*) and the worm snake (*Carphophis amoenus*), second that the copperhead has not been taken at all in the first three months of the year, and only once in December, the two taken in the latter month being both on December 1, thus giving this species a full four months winter vacation.

Again as to the maximum month for separate species we find that the garter snake, ribbon snake, DeKay's snake, red-bellied snake, ground snake, and worm snake, all have April for the maximum month, while May is the optimum month for spreading adder, king snake, brown king snake, and chicken snake, and October for Valeria's snake, ring-necked snake, and green snake, the other species having no decidedly best month or the records are too few to draw conclusions from.

DEPT. AGRICULTURE,
RALEIGH, N. C.

METEOROLOGICAL INQUIRIES FROM THE VIEWPOINT OF 1795

By LEE A. DENSON[1]

Changes in atmospheric conditions from day to day and season to season must have attracted the attention of [illegible]nkind from the earliest times, since nature has provided a way for [illegible]imal life to note these conditions in one form or another. And probably the first observations or signs noted were of repeated appearance, handed down from generation to generation.

Thus it may be safely assumed that proverbs were developed that applied to a particular section or portion of the world. But we know now that these old sayings do not apply to all sections and doubtless much of their value was lost in the confusion of carrying them from one section or country to another.

Ages pass with little more than a maze of local signs of weather changes, and America had been discovered more than a hundred years before man found a means of measuring the temperature and pressure of the air, through the notable achievements of Galileo and Torricelli.

The next step is the first series of observations, and this according to the reports of the Smithsonian Institution, was organized by the Duke of Tuskany in Italy and other countries, beginning in 1654 and continuing for thirteen years. A hundred years pass and other observations are taken up. Some now in America. The first instrumental observations in this country were taken by Dr. John Lining in Charleston, S. C., from 1738 to 1750. Thomas Jefferson kept a daily record at Monticello from 1772 to 78 and in the latter part of the period simultaneous observations with Madison at William and Mary College, and these are said to be the first simultaneous observations in this country.

This brings us to meteorological inquiries from the viewpoint of near the close of the eighteenth century, and here I wish to exhibit volume III of An Historical, Geographical, Commercial, and Philosophical View of The United States of America, by W. Winterbotham, first American edition, published in New York for John Reid, bookseller and stationer, in 1796.

[1] Meteorologist, U. S. Weather Bureau.

Winterbotham says:

Changes in the atmosphere have such important consequences on the affairs of human life, that the art of prognosticating them is very beneficial. It has of late years been cultivated with great assiduity in various parts of Europe, and the series of observations will gradually form a system that may at least unite probable conjectures with much certain knowledge. Several circumstances of the United States point out corresponding inquiries—they are subject to sudden gusts of wind, and some tornados that rapidly pass over a space of one or two hundred miles: from the beginning of spring till the setting in of winter, these occasion many unhappy accidents on their extensive coasts and ample navigable rivers. Their transient strokes are, however, not comparable to those severe storms that generally visit the Americans two or three times in that season: after these, the gazettes announce numerous deplorable shipwrecks, and other disasters; coming from the east with heavy rains, they generally cause inundations, which overflow a vast extent of meadow grounds, on the lengthy rivers and winding creeks, and sometimes damage wharves and stores of commercial towns. A foresight of all these would enable them to elude their fury: vessels might stay in port, or seek a shelter; merchandise might be secured; the hay might be removed, and the cattle, which sometimes perish by the sudden rise of the water. In summer the sudden gusts happen generally towards evening, after a sultry calm for some hours: when attended with thunder and rain, warning is given by the rising clouds: those with a clear sky are less frequent, and preceded only by light eddies in the air for some minutes. The tornados are probably announced by some remarkable symptoms, though their happily rare occurrence has prevented attention; the air is, we believe, very sultry for two or three days, and on the last, somewhat hazy with tremulous light breezes from the west. The easterly storms are ushered in by the gradual thickening of the clouds and increase of the wind for many hours.

The irregularity of the seasons is a great impediment in the business of social life; the fallacious appearance of an early spring often invites the husbandman and gardener to planting and sowing, which will be injured by severe frosts and cold rains. The beginning of winter varies also by several weeks: after the first of December, mild weather is often changed into cold, that within two or three days fills the rivers of the northern and middle States with ice, by which vessels outward bound are detained, and those coming on the coast suffer severely. A greater disadvantage of this variation is, uncertainty of the seeding time, on which much depends the future crop; if it is too early, the luxuriance of autumnal vegetation exhaust the root; if too late, it cannot acquire sufficient firmness to bear the frost. The Americans have two prognostics of winter which are founded in nature: the migration of wild geese shows that the northern waters are freezing, and that they may expect severe northwesterly winds; abundance of rain, by cooling the air and wetting the earth, prepares both for the impression of the frosts; increasing number of partridges, pheasants and other ground birds in the populous parts, with the appearance of bears, doth also indicate that the western woods are already covered with snow. Mild winters are always succeeded by cold springs. Early thunder is a sure token of immediate cold weather for a week or two. The progress of the vernal season

would most probably appear from an accurate *Calendarium Floræ;* the bloom and foliation of some trees being unfolded, not by an occasional warmth of the air, but by a gradual penetration of the heat to their deep roots, proves at least an ascendancy of the vernal temperature not easily overcome by the northerly gales.

The sudden alterations of cold and heat throughout the year, would often be less injurious to health, by foreseeing them: general rules are these, excessive warmth for the season seldom continues above a few days, and quickly changes into the opposite extreme: fine days in winter, spring, and latter part of autumn, are immediately succeeded by cold and wet, rain or snow, according to season and latitude; wherefore they are called weather breeders.

These words, quoted in full, are interesting as representing the viewpoint at the time, and especially in view of later developments. Evidently the results of observations were just coming to light, though far from any well defined system and far also from any possibility of forecasting at the time.

In the succeeding fifty years Redfield, Espy and Loomis are foremost Americans in developing meteorology. The next and most important step in the advancement of forecasting was the invention and perfection of the telegraph. In the American Journal of Science for September 1846 (page 334), W. C. Redfield says:

In the Atlantic ports of the United States the approach of a gale when the storm is yet on the Gulf of Mexico or in the southern or western states may be made known by means of the electric telegraph, which will probably soon extend from Maine to the Mississippi.

This is the first known published suggestion of the use of telegraphy for the transmission of meteorological information, and the practical use was demonstrated by Joseph Henry, in 1849, through the coöperation of the telegraph companies then in existence. The Civil War checked further development, and the organization of a Meteorological Service in this country was not effected until 1870.

From this time on, rules for forecasting have been developed, first for 24 hours, then 32 hours, and 36 to 48 hours. Within the past ten years attempt has been made to give the outlook for weather in a general way for a week ahead. This has been successful in part, so far as the more important changes are concerned, but complications arise at times that thwart the skill of the best forecasters.

In conclusion, it is seen that the development of meteorology and the art of forecasting has been slow; that the viewpoint of 1795, pointed quite clearly to some of the achievements of today; that much remains to be worked out in the future, and science may lead us further into

the mysterious mazes of nature, so that eventually a way may be found to outline the sequence of atmospheric disturbances and the resulting drought or rainy period far in advance of the possibilities of today, and so generations to come may look with equal interest on the viewpoint of 1925. We have come now to the ground work of a world-wide system of observations, and explorations of the upper air are under way. The era of research and investigation is at hand, and the results of meteorological inquiries within the next few hundred years may materially affect the welfare of the human race. Think of the possibilities of successfully outlining the general character of the weather for a month or a season! This is the ideal view; it remains to be seen what may be accomplished in a practical way.

WEATHER BUREAU,
RALEIGH, N. C.

AN OIL-BEARING SHALE OF NORTH CAROLINA

By Frank C. Vilbrandt

In order to acquaint those members of the Academy who are not familiar with the problems in connection with oil-shales I shall give an explanatory foreword before I take up the presentation of the data I have obtained on an oil-bearing shale found in North Carolina.

The enormous yearly increase in the number of automobiles in operation and the increased utilization of the same, bring the average consumption of gasoline per machine per day above that computed by Requa in 1918, which was then 2 gallons. Some estimates amount to double that quantity at present. The increasing need of petroleum oil is steadily outdistancing the visible supply to such an extent that there appears to be an exhaustion of the oil reserves in fifteen years, according to one authority. To offset this impending depletion, intensive surveys and drillings are being carried on to find new oil-fields; better methods of refining are being sought; greater recovery of the oil from the oil sand is being investigated, to increase the recovery above the 10% that is being obtained at present; substituting electricity for gas power; utilization of the by-products from coal; substitution of alcohol in part for motors gasoline; utilization of vegetable oils for lubricants; and the recovery of oil from the shales so prevalent in the United States.

The United States Bureau of Mines believes that the oil-shale deposits of this country can be relied on to serve as the future oil reserve, that the combined shales that bear oil will be sufficient to take care of our power fuel for some time to come. The future of the shale oil industry, therefore, depends primarily upon the relative supply of and demand for petroleum products, particularly in the regions remote from the seaboard.

It appears as if, no matter which substitute for petroleum products will be found to be developed to its greatest extent, whether electricity, coal or alcohol, there does not exist any satisfactory substitute for the production of petroleum oil lubricants except shales. Although the presently produced lubricants from shales are similar to the light petroleum lubricants, not satisfactory for heavy duty service, changes in methods of refining are expected to develop them.

At present the tonnage of shale distilled for the production of shale oil does not exceed 10 million tons (with Scotland and Australia contributing over 6 million of these), the recovery of shale oil varying from 7 gallons per ton from one of the Elko, Nevada, shales to 170 from the Hartley shales of Australia. In order to supply the demands for mineral oils from shale to supplant that from petroleum wells, it would be necessary to operate 1900 shale retorting plants of 1000 tons capacity, working on average shales producing 42 gallons of oil per ton, involving an investment in retorting and refining plants of one-quarter billion dollars. Six hundred ninety-four million tons of shale would have to be treated each year. One of the Utah shale deposits alone contains four billion tons, sufficient to take care of our needs for seven years.

Oil is not the only product obtained from shales. During the process of retorting, ammonium sulfate, the concentrated fertilizer, together with a shale gas of low heating value accompanies the production of the shale oil. The shale oil itself is further refined by pyrolysis and treatment into finished naphtha, heavy naphtha, motor boat oil, light and heavy burning oil, light and heavy gas oils, soft and hard paraffines, lubricating oil and petroleum coke.

As to what constitutes an oil shale, a few definitions will tend to bring this out clearly. According to Gavin (Bur. Mines Bull. No. 210, page 26, 1924) shale is a compact, laminated rock of sedimentary origin, yielding over 33% of ash and containing organic matter that yields oil when distilled, but not appreciably when extracted with the ordinary solvents for petroleum. Although the line of demarcation between coal and shales is not sharp, the 33% ash content has been suggested as the most feasible line. When a rock contains organic matter, it is termed carbonaceous or black shale; when it contains bituminous substances, it is termed bituminous shale, and when so rich in bitumens as to yield gas and oil on distillation, it is called an oil shale.

To all intents and purposes, oil shale contains no oil as such, the source of oil being an organic substance termed "kerogen," which is very likely not a definite chemical compound, but is made up of molecules of various types and sizes, the oil-yielding kerogen of different shales being unlike chemically. Kerogen, distributed throughout the shale in globlues or irregular streaks, ranging in color from yellow or reddish yellow to dark brown on nearly black, as such, is of no practical value, but by heating, or pyrolysis, its complex molecules are cracked to form simpler gaseous, liquid and solid hydrocarbons and their derivatives, more or less similar to those derived from oil well petroleums.

The oils produced by pyrolysis consist chiefly of the paraffine, olefine, diolefine and naphthene series and their derivatives, with possibly some aromatics and acetylenes.

The mineral matter in shales consists mainly of clay, with sand grains and pyrite, the shale having been formed by the consolidation of clay, mud, or silt.

STUDY OF NORTH CAROLINA SHALES

The present study of North Carolina shales is a result of a coöperative effort with the North Carolina Economic and Geological Survey (now the Department of Conservation and Development) under former

TABLE I

FORMATION	DEPTH	MATERIALS	THICKNESS OF FORMATION
No. 16	268 feet	Black shale	7 feet
20	355 feet	Black shale	32 feet
23	564 feet 4 inches	Black slate and shale	8 feet
25	604 feet 5 inches	High grade coal	3 feet 10 inches
26	608 feet 3 inches	Black band	1 foot 6 inches
27	609 feet 9 inches	Low grade coal	1 foot 10 inches
28	611 feet 7 inches	Black band	9 inches
29	612 feet 6 inches	Black slate	1 foot 0 inches
34	642 feet	Black band	3 feet 0 inches
35	645 feet	High grade coal	1 foot 10 inches
36	646 feet 10 inches	Black band	2 feet 10 inches

Director Drane. W. E. Giles, a research student of the University, is responsible for the laboratory analysis and some of the heat tests. A continuation of the work is being made by myself and the Survey to include all the shales of the state. This work will tie up with the work being conducted by the Bureau of Mines in the following states by coöperation of the different state surveys and the government laboratories. The states at present included in the national survey are Colorado, Utah, Wyoming, Montana, California, Missouri, Illinois, Indiana, Ohio, Pennsylvania, Kentucky and Tennessee.

The oil-bearing shale that was studied and is being presented to you is found in the Carboniferous era, overlying and underlying the coal in the Deep River coal field of Moore, Lee and Chatham counties. The particular sample studied was taken from the mine and waste pile of the Erskine-Ramsay Coal Company at Cumnock. The sample is a

composite of some samples collected by Dr. W. T. Prouty of the Geological Survey and by W. E. Giles and myself, taken from as many different locations on the face and in the waste heap as was deemed necessary to make it a representative sample of the black band shale vein of the coal field. The field shows little variation in thickness of the various strata of rock and coal. A log from a diamond drill hole, located approximately one-half mile south west of the Cumnock Shaft on the banks of the Deep River shows the interesting data given in table I.

Formations 25, 26, and 27 mark the mining operations for the recovery of coal from the No. 25 formation. The narrowness of the coal vein on the slopes makes it necessary to work under extremely low ceilings, the heighth of the walls varying from 37 inches to 52 inches. Most of the workings are approximately 48 inches high. Seam No. 27 is too poor a grade of coal to make it profitable to mine for stream coal and probably also for powdered fuel, but if formations 26, 27 and 28 could be utilized for some commercial product, the effective heighth of the chambers could be increased to 8 feet. Two layers of fire clay totaling 16 feet 6 inches lie below these workings and above formations Nos. 34, 35 and 36. The coal in seam No. 35 has been found to be a good coal but the thinness of the vein, 1 foot 10 inches would require the removal of Nos. 34 and 36 with it to give working room.

In this investigation all the slate and shale formations are being studied. At present only the data on a composite sample of formations Nos. 26 and 28 have been compiled for presentation, but formations Nos. 34 and 36 being similar in composition by analysis can be assumed to give similar results on distillation. Formation No. 23 has been tested sufficiently to show it to be oil-bearing, but quantitative data are not yet available.

ANALYTICAL DATA

The method adopted for this study was the maintained temperature distillation at temperatures between 500° and 1200°F. This differs from the Bureau of Mines method, but was adopted because it enabled a better comparative study of the coals and shales that were in contact with each other, a continuation of low temperature studies of the Deep River Coal field products by Mr. Giles. Analytical studies are being made on each individual formation in this region as well as of other sections of the state according to the Bureau of Mines method.

A summary of the production yields on retorting the above shales calculated on the basis of one ton is given in table II.

TABLE II

Production Yields of Black Band Shale

	TEMPERATURE OF DISTILLATION			
	900°F.	1000°F.	1100°F.	1200°F.
Spent shale (pounds per ton)	1,684	1,624	1,662	1,656
Shale gas (cubic feet per ton)	467	467	512	734
Ammonium sulfate (pounds per ton)	8.3	10.8	9.7	9.8
Shale oil (U. S. gallons per ton)	10.7	12.7	10.2	10.3
Naphtha and spirits (U. S. gallons per ton)	4.8	4.5	3.7	5.6
Kerosine (U. S. gallons per ton)	0.4	0.8	0.9	1.2
Gas oil (U. S. gallons per ton)	0.7	1.2	0.9	1.1
Fuel oil (U. S. gallons per ton)	1.1	1.3	1.1	1.6
Lubricating oil and waxes (U. S. gallons per ton)	2.2	2.7	1.7	0.7
Coke (pounds per ton)	8.6	14.2	11.3	5.5

TABLE III

Analysis and Yields of Oil Shales of the United States

LOCATION	$(NH_4)_2SO_4$	SHALE OIL	MOISTURE	VOLATILE AND FIXED CARBON	ASH
	lbs./ton	*U.S. gals./ton*			
Nevada, Elko	40.5	32.52	2.40	33.5	64.4
	14.1	7.28			
Kentucky, Clay City	58.5	18.22	0.70	29.3	70.0
Utah, Soldier Summit	54.7	44.60	0.8	38.1	61.1
Colorado, DeBeque	90.5	60.15	0.1	42.3	57.6
	71.7	48.77			
Utah, Dragon	69.8	41.65	1.1	42.2	56.7
	37.7	21.70			
Wyoming, Green River	33.0	23.45	0.25	34.95	64.8
	78.2	58.65			
California, Ione	36.8	52.00	8.50	62.9	28.6
North Carolina, Deep River	10.8	12.7	0.85	27.33	71.8

A comparison is made of this shale with the shales of other sections of the United States in table III according to yields of products and analysis.

One holding in the Deep River Coal field has available in the black band studied in this investigation, 47,390,000 tons of this shale. If the estimates of the Geological Survey are correct for the coal in the entire field, there must be 165,865,000 tons of oil-bearing shale in this one kind of formation, excluding all other possible and brown oil-bearing strata in the field. Taking the data from the optimum conditions obtained in table II a compilation was made to estimate the possible resources in this one formation. These data have been tabulated in table IV. These figures are totals on the black band only, with possibili-

TABLE IV

Estimates of Shale Oil Products in the Deep River Coal Field

MATERIAL	KNOWN HOLDINGS OF ONE COMPANY	ESTIMATES ON THE ENTIRE FIELD
Shale gas, (cubic feet)	21,131,130,000	73,958,955,000
Ammonium sulfate (pounds)	511,338,100	1,789,683,350
Shale oil (U. S. gallons)	604,222,500	2,114,779,350
Spirits and naphtha (U. S. gallons)	213,321,500	746,625,250
Kerosine (U. S. gallons)	37,912,000	132,692,000
Gas oil (U. S. gallons)	57,815,800	202,352,600
Fuel oil (U. S. gallons)	62,554,800	218,941,800
Lubricating oil and waxes (U. S. gallons)	128,900,800	451,152,800
Coke (tons)	336,469	1,177,638

ties of increasing the quantities by findings in 39 feet of shale not yet tested and the 8 feet known to be oil bearing, the latter formation amounting to 146,090,000 tons.

The actual cost of production of a barrel of shale oil from this source cannot be estimated, but when one considers what difficulties must be met before the shales in the Rocky Mountain region becomes available, outcropping up in the walls of the canyons and lying at altitudes of 45,000 and 80,000 feet, one can understand that the difficulties in mining in the Deep River field are not insurmountable. Most of the western shales are covered with comparatively thick over-burden. Many mining engineers claim that the western shales will cost about as much for mining as coal, since coal mining conditions will have to be met. Gavin estimates the cost of mining of shale to constitute 53% of the cost of shale oil production. In such a case the costs in the Deep

River field would be distributed so that the mining costs would be less, inasmuch as the utilization of the shale would reduce the cost of coal mining sufficiently to enable the utilization of the poorer grades of shale.

The shale gas produced from this shale has a low heating value but could be used for several industrial operations in connection with ceramic ware manufacture and other industries.

Possibilities for the creation of a center of industries in this region with its coal, its oil shales, its timber and its clays are good.

UNIVERSITY OF NORTH CAROLINA,
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RECENT DEVELOPMENTS IN THE CHEMICAL INDUSTRIES OF NORTH CAROLINA

By Frank C. Vilbrandt

This survey of the chemical industries of North Carolina is the second of a series made for the purpose of keeping a record of the progress along chemical lines. The first of these surveys was made in 1921–1922 (Journal of the Elisha Mitchell Society, **39**: 76. 1923) and at that time the remarkable growth of the chemical industries of the state was revealed by the summary of the statistics obtained at that time. Further rapid expansion was predicted at that time. Two years have elapsed since that time with a period of depression of minor order in the cotton milling industry. In what manner the chemical industries suffer will indicate to what degree the chemical industries of the state are dependent or allied to the other industries.

A study of a compilation of the data on all the industries of the state as given in table I shows that in general there has been a considerable check in the rapid development that seemed certain two years ago, amounting almost to a set-back, although in volume of business it is still almost double that of a decade ago.

The statistics show that there were 337 chemical or allied plants in operation in 1924, employing 10,656 people, who received $8,640,700 in wages, for which they turned out $67,936,583 worth of products on an estimated capital investment of $97,562,840. Comparing the same industries two years ago, this shows a decrease of 25 plants, with 682 people less and a loss in yearly payroll of $2,322,300. A loss of $138,703,417 in value of products, accompanied by a reduction of $22,083,160 in capital invested. On first glance this looks like a tremendous set-back for the chemical industries and that these industries were experiencing some kind of check. In order to understand this, let us compare the statistics of all the other industries of the state with those obtained for the chemical industries to see whether this depression was widespread or specific for this group of industries. The data for all the major industries in the state for 1924 and 1922 have been tabulated in table I.

An analysis of the data in table I shows that, although there have been some set-backs, that the extent for all the industries is relative to that which occurred to the chemical industries. The chemical industries

TABLE I

Rating of Manufactories in North Carolina in 1924

INDUSTRIES	CAPITAL INVESTED	ESTIMATED PLANT VALUATION	ANNUAL PRODUCTION VALUE	YEARLY PAYROLL	EMPLOYEES	NUMBER OF PLANTS
Cotton mills	$168,292,592		$252,078,364		83,728	386
Tobacco plants	110,000,000	$50,198,170	251,555,165	$14,172,446	17,174	17
Chemical industries	97,562,840	23,995,333	67,936,583	8,640,700	10,656	337
Fertilizer	64,028,000	3,950,000	14,354,000	1,922,000	2,278	40
Cottonseed products	5,542,000	2,725,000	13,585,000	919,500	1,202	38
Tanning	8,711,100	1,980,000	11,000,000	978,000	974	10
Paper and pulp	3,000,000	2,807,000	6,036,000	1,287,000	1,120	1
Ice	2,916,000	3,365,000	2,858,000	846,000	1,091	49
Drugs	1,540,000	1,218,000	3,334,000	396,300	354	20
Tires	4,161,340	1,076,000	2,300,000	325,000	310	3
Ceramics	1,730,400	1,920,333	4,571,000	1,081,900	1,755	71
Gas	2,815,000	1,989,000	879,000	412,000	222	25
Minerals	2,123,000	1,640,000	4,489,583		561	74
Dyeing, mercerizing, etc	976,000	1,295,000	4,500,000	465,000	619	5
Turpentine and rosin	20,000	30,000	30,000	8,000	150	1
Knitting mills	33,994,485		29,058,702		12,781	131
Furniture factories	12,734,849	10,805,846	41,619,806	7,799,901	11,181	99
Woolen, silk and cordage mills	5,993,200		7,801,164		2,454	17
All others	161,520,717	84,129,412	199,286,398	37,616,445	43,242	1,735

TABLE II

Table of North Carolina Industries for 1922 and 1924

INDUSTRIES	CAPITAL INVESTED		ANNUAL PRODUCTION		EMPLOYEES		NUMBER OF PLANTS	
	1922	1924	1922	1924	1922	1924	1922	1924
Cotton mills	$200,000,000	$168,292,592	$285,000,000	$252,078,364	73,600	83,728	450	386
Tobacco plants	130,440,000	110,000,000	225,000,000	251,555,165	9,300	17,174	23	17
Chemical industries	119,646,000	97,562,840	206,640,000	67,936,583	11,338	10,656	362	337
Knitting mills	31,150,000	33,994,485	33,000,000	29,058,702	16,500	12,781	175	131
Furniture factories	16,000,000	12,734,849	40,106,000	41,619,806	14,000	11,181	124	99
Woolen mills	2,800,000	1,898,000	3,400,000	3,723,300	951	1,557	9	10
Silk mills	2,000,000	3,060,000	1,800,000	2,348,952	874	639	3	2
Cordage mills	55,000	1,035,200	300,000	1,728,912	42	258	2	5
All others	455,000,000	161,520,717	47,247,250	199,286,398	60,000	43,242	5,270	1,735

have maintained their relative position with no apparent threats for a dethronement for some time to come, although a possibility exists for the advance of the chemical industries into second place, should a bigger slump occur in the tobacco industry.

It is apparent that all of the industries have suffered during the last two years, not only in the capital invested but also in the value of products produced. Cotton milling shows a reduction of 64 mills, a reduction of $431,707,408 in capital invested, with a loss of $32,921,636 in products, but an increase in the number of employees by 10,128. The tobacco plants register a loss of 6 in number with a reduction in capital invested by $20,000,000; however, the high cost of smoking has enabled this industry to increase the value of their products by $26,555,165 and give 7874 more people employment. Although there has been an advance of $2,844,485 in capital invested in the knitting mills, 44 fewer establishments are operating, 3719 fewer people working in the mills and a loss in value of products approximating $4,000,000. The furniture factories show a decrease of 25 plants with a loss of employment to 2819 people and $3,265,151 in capital, but an increase in value of products amounting to $1,513,806. The woolen, silk and cordage mills taken as a group have shown remarkable advances in the last two years, having felt the depression the least of all. The miscellaneous industries that have not been included in any of the above show the greatest loss during the last two years. There has been a reduction of 3535 establishments, a loss in employment to 26,359 people, a loss in capital invested of $392,473,123, but an increase in products handled of $82,902,565.

Although it is unfortunately impossible to obtain the data on water purification plants and that of the gigantic aluminum reduction plant of the Tallassee Power Company at Badin, to include with the chemical industries' data, their omissions do not affect the above comparisons because they were likewise lacking in the previous report.

In order to determine where the losses occurred in the chemical industries, the individual classes of chemical industries will have to be studied separately.

FERTILIZER

The fertilizer industry contributed a loss of 17 establishments in the last two years with a reduction of $15,722,000 in capital and $17,566,000 in value of products, using 383 more employees but paying practically the same annual payroll. Reverses met by the biggest fertilizer com-

bine in the state has had much to do with the losses incurred, but there seems to be no doubt that this industry will again make big strides forward, inasmuch as the demand for its products is ever-present and ever-increasing to take care of the increased demands made upon agriculture. There were 40 fertilizer plants making superphosphate, fish scrap and electro-phosphoric acid, with a total capitalization of $64,028,000 and a plant valuation of but $3,950,000, producing products valued at $14,354,000 by 2278 employees receiving $1,922,000 for their wage. The fertilizer industry is scattered throughout the state.

COTTONSEED PRODUCTS

The year 1924 registered 38 plants engaged in producing cottonseed oil or refining the same, entailing an investment of $5,542,000 on a plant valuation of $2,725,000, but producing only $13,585,000 worth of products with 1202 employees whose annual payroll aggregated $919,500. The combined cottonseed industry contributed a loss of 18 plants over 1922, a reduction of $6,458,000 in capital invested, a loss in plant valuation of $25,275,000, with the enormous loss in production values of $120,015,000 together with 1048 less employees and a loss to the payroll of $745,500. In value of products this one industry contributed about 88% of the loss in 1924 over 1922. The losses have affected the larger companies more than the smaller ones, some of the smaller plants showing gains. The cottonseed industries are well scattered throughout the cotton growing belt of this state.

LEATHER

The leather and tanning industry has retained its position as the third largest chemical industry in the state with but little change over two years ago. The 10 plants still operating have shown but little change in management, practically no change in the capital invested, plant valuation, employees and payroll. The products made have netted a bigger return over two years ago by about $1,000,000. The capital investment of the 10 plants for 1924 is $8,711,100 upon a plant valuation of $1,980,000 putting on the market $11,000,000 worth of products by 974 employees receiving $978,000 in wages. The industry is located in western North Carolina, in the mountain region, where soft water is to be had in abundance and at no cost for purification, and also near the source of supply of the tan.

PAPER PULP

Only one paper plant made a report of activities in 1924, but this plant was the largest, the losses being practically those of this plant. The capitalization amounted to $3,000,000 with a plant valued at $2,807,000, producing $6,036,000 worth of products, employing 1120 employees to whom a total wage of $1,287,000 was paid. The reduction in capital for this industry over two years ago amounted to $3,850,000 with a loss in plant valuation of $1,342,000, giving employment to 280 less people, but a loss of only $93,000 in wages. The one plant reporting, The Champion Fibre Company, is located at Canton in the mountains of western North Carolina near the source of spruce for the making of Krafft paper, by the sulfate process.

MANUFACTURED ICE

Our twentieth century commodity, manufactured ice, follows modern development, and therefore but little change would be expected in this industry even in time of depressions. In spite of a loss of 6 plants over two years ago, there has been barely any changes in finances connected with the manufacture of ice. It is pleasing to note that the wages of the employees in the industry have been materially increased, as indicated by increase in the annual payroll of $236,000 for about the same number of employees, *i.e.*, for 1091 people. The ice industry showed an investment of $2,916,000 for the 49 plants valued at $3,365,000 producing $2,858,000 on a payroll of $846,000. Ice plants are located in all the large cities in the state, the larger cities being supplied with two. The rapidly increasing population of the cities will create a bigger demand for this commodity.

DRUGS AND MEDICINES

North Carolina holds a unique position in supplying the United States with the greatest variety of drugs and proprietory medicines on the market by small dealers in contradistinction to the drugs and medicines placed on the market by the large drug firms. The products so classified run the gamut of proprietory articles from treated sawdust for sweeping, shoe dye and shine, liniments, salves, headache potions and special prescriptions. The 20 such establishments have a capitalization of $1,540,000, a plant investment of $1,218,000, selling $3,334,000 worth of products, providing employment to 354 people for a combined payroll of $396,300. The loss incurred over two years amounts to

9 plants, with a decrease of $3,056,000 in value of products, causing a reduction of employees to one-half with one-half the payroll. The larger establishments of this sort are located in the larger cities of the state.

RUBBER TIRES

Although but seven years old, this industry bids fair to make its impression as time passes. The increasing number of automobiles in use in the state calls for a greater consumption in tires. The service that has been obtained with tires manufactured in this state speaks well for the excellency of these products. Three plants reported in 1924 a total investment of $4,161,340 and a plant valuation of $1,076,000 and a production value of $2,300,000 by 310 employees receiving a total pay of $325,000. A loss of $2,500,00 in value of products over two years ago is partly accounted for by the drop in the cost of tires and partly by the fact that one of the companies went into receivers' hands during this time, reporting no production values.

CERAMICS

In the ceramic ware industry there has been quite a loss incurred in the last two years. The 71 plants register 32 less than in 1922 with a small reduction in capital due to the inoperation of some of the smaller plants. The larger plants have been busier, the entire industry using 1755 employees, 700 more than in 1922, increasing the plant valuation $420,000. The total capital invested in 1924 was $1,730,400 upon a plant valuation of $1,920,333, producing $4,571,000 and handling a payroll of $1,081,000. Against two years ago, when there were 35 plants with a capitalization, plant valuation and production of less than $5000 each, today there are but 31, and where only 11 exceeded $50,000 two years ago, today there are 25. The ceramic plants are distributed as follows: 51 brick plants, 7 pottery and crockery yards and 11 yards producing various forms of cement products.

GAS

Excluding the 2 pintsch gas plants, which began operation in this state in 1889, the gas industry of this state is recent, beginning in 1910, having progressed from 6 in operation at that time to 12 two years ago to 25 at present. The totals for 1924 are $2,815,000 capitalization on a plant valuation of $1,989,000 with a production of $879,000 of gas, employing 222 men on a payroll of $412,000. Future expansion

in this industry will come with the growth of cities and towns and the demands for gas in the smaller municipalities.

MINERALS

The year 1924 registers a good year for mining operators, about three times the value of products produced over two years ago, with a doubling of the capitalization. The capitalization mounted to $2,123,000, upon a property valuation of $1,640,000, while the value of products increased to $4,489,583. Employment was given to 561 people. Among the individual minerals mined are granite, sand and gravel, kaolin, feldspar, limestone, mica, iron, coal, talc and prophyllite. The last two years have seen some very active work being carried on in the Deep River coal fields.

DYEING, MERCERIZING AND BLEACHING

Although the state showed a considerable slump in the cotton and knitting milling over two years ago, there has been more effort directed to finishing the fabric here in North Carolina instead of sending it into the North for dyeing, mercerizing and bleaching, by building and operating two more such mills, bringing the number to five, with a total capitalization of $976,000 on a plant valuation of $1,295,000 and a production value of $4,500,000, employing 619 people for a yearly wage of $465,000. The production values have increased from $570,000 two years ago to $4,500,000 in 1924. It is gratifying to note that capital in being invested in this state for the treatment of cotton goods here instead of diverting the work to out of state plants. In the above summary is not included several small dyeing and bleaching plants connected with some of the large cotton mills and upon which returns have been included in the cotton mill data.

TURPENTINE AND ROSIN

This state will rapidly become a non-producer in this commodity if efforts are not directed toward a better conservation plan. No industry, however, is so firmly controlled as this one by "factors" who regulate prices from other states. The sharp rises and declines have left 1924 with only one important operation at Wilmington, the smaller estate operations being discontinued. One hundred fifty employees on an aggregate payroll of $8000 produced $30,000 worth of turpentine, rosin and pine oils, on a plant valuation of the same amount and a capitalization of $20,000.

LAUNDRIES

Although chemists do not live in laundries and very few live on them, it is becoming more and more evident that progress in this industry depends on the chemists and they are being called upon more than ever to make studies of the processes used, not only for making the plant more efficient but for assisting in increasing the quality of work. Although these plants are not included in the summaries of the chemical industries, since they were omitted in 1922, an indication of their rising importance in the state can be obtained by noting that 40 plants, employing 1576 people on an aggregate payroll of $989,500 has brought in a revenue of $2,095,000 to their owners on a plant valuation of $1,408,000 and upon a capitalization of $762,000.

MISCELLANEOUS

In order to complete the data, mention must be made of the very small paint plant at Wilmington and the 2 asbestos textile plants located in the Piedmont. The paint plant totals but $17,000 capitalization and a production sum of $15,000, while the two asbestos plants have a capitalization of $441,000, a plant valuation at $500,000 a production value of $1,200,000, giving employment to 215 people for an annual payroll of $265,000.

With the future developments of our natural resources and the establishment of more mills in the state due to its favorable climatic and labor conditions, there seems to be no doubt but that the chemical industries will likewise grow and extend themselves, offering employment to scientifically trained men. North Carolina with its water power, its large coal field, its many minerals, its cotton and tobacco industries, its spinning and knitting mills, its finishing plants, its agricultural developments can always look forward, and need not feel alarmed at a slight check in its progress, which may be only a pause for greater things to come.

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INVESTIGATION ON THE GERMINATING AND HEATING OF COTTON SEED IN WAREHOUSE STORAGE

By E. E. Randolph

Since ancient times in many countries olive oil has been the principal cooking grease. The cotton plant is historically as old as the olive tree, but not until within the past forty-five years have people realized the value of the oil. Until 1890 a large per cent of the oil went to soap kettles. Dr. Wesson's discovery of a method of deodorizing the oil, and the discovery fifteen years ago of a method of hydrogenating the oil, have made the oil equal to olive oil and perhaps a more wholesome fat than hog lard. It is now used as an edible oil and fat in almost every American home—a hard fat, oleomargarine, a fine grade of cooking oil, and a salad oil. The competitors of cotton seed oil are butter, hog lard, olive oil, soy bean oil, peanut oil, and, to a limited extent, certain other vegetable oils.

The production of cotton seed products has become one of the major industries of the United States. From August 1, 1924, to March 1, 1925, according to the Bureau of Census 4,440,000 tons of seed had been received at the mills, approximately $\frac{2}{3}$ of which had been crushed, yielding crude oil 1,245,564,500 pounds, refined oil 1,043,137,000 pounds, cake and meal 1,892,000 tons, hulls 1,183,000 tons, linters 792,300 bales, hull fiber, grabbots and motes 100,000 bales of 500 pounds.

The fatty oils, fats, and waxes are of animal origin or vegetable origin. Chemically the fatty oils and fats are esters of fatty acids and glycerol, called glycerides. Glycerine is a tri-hydric alcohol. The waxes are esters of complex fatty acids and monohydric alcohol of the methyl alcohol series. Fats are solid and oils are liquid at ordinary temperatures. The oil of the plant is found largely in the seed. The oils are non-drying as olive and castor bean oil, semi-drying as cotton seed and sunflower oil, and drying as linseed oils. Petroleum oils are hydrocarbons and are not used for human food. Glycerides are not highly stable bodies, but are broken down on standing, and by light, heat, and moisture into the fatty acids and glycerine. Both acids and alkalis decompose them when heated.

The following fatty acids are found free or in their glycerol ester in cotton seed oil:

Oleic, $C_{18}H_{36}O_2$, M.P. 14°C, 35 to 40 per cent

Linoleic, $C_{18}H_{32}O_2$, M.P. − 18°C, 35 to 40 per cent

Palmitic, $C_{16}H_{32}O_2$, M.P. 63°C, about 20 per cent

Stearic, $C_{18}H_{36}O_2$, M.P. 89°C, under 5 per cent

sometimes with small quantities of arachidic and myristic acids. Certain colored cells in the kernels give to the crude oil a reddish-brown color. In different seeds small quantities of other substances give the distinctive odors. The fatty acids in cotton seed have each one replaceable hydrogen atom whereas glycerol is trivalent. Triolein, tripalmatin and tristearin have each one glyceryl radical and a triple radical of the corresponding acids. It has been found that not only the amount, but also the nature of the oil varies with the kind of seed, climatic conditions, and other factors. This variation seems to indicate that the glycerides do not always contain the same acid radicals or in the same proportion. It also shows that we may not have a glyceryl radical combined always with three of the same acid radicals. In fact it seems that sometimes each of the OH radicals has been replaced with different acid radicals (illustration). Then, too, if we designate the hydroxyl radicals by a, b, c, a different property is observed when the acid radical is in different positions.

Formerly the crushers and refiners made a good profit in their respective lines of work. This fact caused a large increase in the number of mills. There are 56 cotton oil mills in operation in North Carolina, which crushed 325,000 tons of seed last year. South Carolina has 83 mills. The mills increased so rapidly, in fact, that we have sufficient mills to crush the seed from a 16,000,000 bale crop. Attending these increased numbers and capacities came a number of evils. Among these may be mentioned the facts that in order to keep the mills running keen competition arose in buying seed. Large warehouses were built. Strong buying occurred at the beginning of the season. This fact boosted the prices to the farmers at the beginning of the season. When warehouses were full the price of seed diminished for bulk of his crop. To handle the seed quickly the mills run night and day increasing fire risk and broken machinery. Much interest had to be paid by millers for stored seed, and by refiners for stored crude oil. Oil is not furnished throughout the year to consumers and soap makers. Meal and hulls are not furnished continuously to dairymen. Large quantities of seed stored

frequently heat and depreciate, if bought too green or damp. Not only the amount but the quality of the oil is seriously impaired from heating caused largely by fermentation and germination.

During the month of September extensive and continuous rains damaged a large per cent of the first part of the season. Much of the seed actually sprouted in the field. These germinating and damp seed underwent considerable change in the warehouse. These chemical changes such as resulted from the broken, bruised and germinating seed, caused much loss in the value content of the seed.

The process of digestion of the stored food in the seed by the germinating embryonic plant seems to be the reverse of the storage of food process. The starch seems to be broken down into sugar for food and to enter the cellulose formation of the cell. The curve of the starch content of the seed seems to be steady down and sugars begin to appear. The protein content of the seed seems to be entering into the structure of the plant. The oil, too, shows a steady decrease, possibly being broken up by enzymes into glycerine and fatty acids which enter into the structure or operations of the plant. In addition to the natural changes in the oil content, heating caused by fermentation and oxidation further complicate the matter by causing a loss of oil, as well as by causing a radical change in the nature of the oil content.

Arising from the unusual weather conditions in the early fall which caused a high percentage of damaged seed, the Interstate Crushers' Association were very much concerned as to the equitable adjustment of the purchase price of seed. Indeed the percentage of oil in the seed could be determined in the bulk, but the farmer selling his seed from a few bales could not be sure that he was receiving what his seed were worth. On the other hand the millers did not know what quality of oil could be obtained, and for what use the oil could be sold. In an effort to adjust the price several arbitrary scales were followed by different millers. But the Interstate Crushers' Association adopted as one of its official rules a basis of grading seed and a scale of deductions for damaged seed.

Rule 40. *Prime Cotton Seed.* Prime cotton seed shall be cool, sound, not containing excess of 6 per cent of damaged or immature seed; clean, that is shall not contain in excess of 1 per cent foreign matter; dry, that is shall not contain in excess of 10 per cent of moisture; and shall be untreated by either chemical or mechanical process other than the ordinary process of ginning.

Rule 140. *Adjustment and permissible variation as to grade and quality.* When seed not of contract quality are accepted, deductions at the rate

of the delivered price shall be made for each per cent of damaged and immature seed in excess of 6 per cent, to be made after deductions for excess foreign matter and moisture.

Grade	*Deductions from delivered price*
No. 1. 0–6 per cent	0
No. 2. 7–14 per cent	½
No. 3. 15–30 per cent	3/5
No. 4. 31–50 per cent	3/4

The reason for such deductions is that the oil from such damaged seed can not be used for food and the feeding qualities of the residues are also inferior. The scale of deductions seems to be out of proportion to the good seed remaining in the lot, but as yet no very satisfactory method has been devised for separating the damaged from the prime seed.

Two new gins are operating in the state for ginning bolly cotton. This cotton is gathered before it is fully opened and after frost. A good grade of cotton can be procured from such bolls provided the cotton has matured fairly well in the bolls. This new method saves for the farmer many thousands of dollars in recovered cotton. The seed are suitable to return to the fields as fertilizer. If these immature and frosted seed are put on the market for oil the situation will be further complicated. This situation, however, can be managed when we learn more about damaged seed. Such gins are rather common in Texas, and the results during the past year in North Carolina are favorable.

The scope of this investigation is to seek for the facts about the deterioration of seed for oil and feed purposes on germination and on heating in storage as a basis for value adjustment, and to find if possible the best feasible method for preventing deterioration in storage. Considerable work has been done but the results are not complete. The results of the oil depreciation on germination in per cent is plotted against days. For the first three days the curve is almost regular, representing a drop of from 19.5 per cent of oil to 16.75 per cent. Then there is a less gradual loss of oil until the young sprout begins to show through the hull on the sixth day—during which period the oil content drops from 16.75 to 7.5 per cent. Then the drop is rather rapid, approaching 0 per cent about the fifteenth day. After the seeds had sprouted the young plant was included in the analysis.

Work has been done on the changes in percentages of oil changes during warehouse heating. The results just given represent what was

found from the germination of good seed. The matter is greatly complicated when all the factors are involved in the warehouse heating. The results are not yet far enough along to report because satisfactory checks have not yet been obtained because of the varying conditions which have to be taken into account.

A slight heating in the warehouse does not affect the quality of the oil seriously, but a rapid heating indicates serious chemical changes. In fact the amount of oil does not drop appreciably in the usual slight warehouse heating, provided the seed can be worked while they are still moist, but when the seed have gone through a heat and have dried considerably less oil can be obtained.

North Carolina produces nearly a million bales of cotton a year. Its mills crush an average of 325,000 tons of seed, and it has one large refinery, the value of whose products render the cotton oil industry a major enterprise in the state.

PROGRESS ON STATE INSECT SURVEY WITH COMPARATIVE DATA ON OTHER ANIMAL GROUPS

By Franklin Sherman

For some years a "Survey of the Insect Life of the State" has been a project for study by the writer and his associates, particularly Mr. C. S. Brimley, who has been especially engaged in this work since 1919. The collecting, classifying and recording of the numerous species is a work of many years, and even when a certain group has once been explored quite thoroughly it will require revisional study after a few years to keep pace with recent discoveries and changes.

Papers pertaining to this Insect Survey have been presented before this Academy, and published in the Journal of the Elisha Mitchell Scientific Society; other papers have been published elsewhere, especially in Entomological News.

In 1890 Dr. John B. Smith published the "Insects of New Jersey" in which 6098 species were listed, many of which were assumed to occur but not confirmed by actual records. In 1900 he issued a revised edition in which a less proportion were assumed species, yet the number was increased to 8537 species. In 1910 he issued a third, revised, list in which the proportion of merely assumed species was further reduced, yet the number listed was increased to 10,385 species. We understand that the many skillful collectors who collect in New Jersey are still constantly adding to the New Jersey list.

Only one other state has issued a list of all its known insects,—in 1920, Dr. W. E. Britton published a "Check-list of the Insects of Connecticut." This state, like New Jersey, has received attention from considerable number of collectors, and the list is more recent but the state is smaller than New Jersey, is farther north, and the list includes only species which are backed by records accepted as reliable. This Connecticut list gives 6781 species.

New York probably has more species of insects on record than any other state, especially because of the large number of collectors who reside within the state. But New York has never issued a list, no one has heretofore brought the records together. Recently, however, Mr. M. D. Leonard has been engaged and located at Cornell University with the duty of compiling and editing the records for publication. We

understand that about 100 collectors are furnishing lists and notices have recently been published to the effect that it is expected that the list will include about 16,000 species. This estimate is of course subject to revision, possibly downward; yet even if it does contain 16,000 species or even more, all experience indicates that collectors will still continue to find yet other species which are not listed.

For the benefit of the layman who may hear or read this paper it may be said that this continual finding of insects not heretofore known is not because the species are new on the face of the earth, but rather that they have recently been identified, or their presence has recently been put on record. It is the findings, rather than the insects, which are genuinely new.

To secure an accurate record of the insect fauna of a locality requires the painstaking accumulation of thousands of specimens correctly preserved and labelled, later to be identified by entomologists who are specialists in the various groups of insects. In North Carolina the insect fauna must thus be explored in many different localities, at different times in the year, and over a long series of years, before even an approximation can be reached,—and always (as yet) there remain groups of insects which have not been adequately collected, or in which the classification is uncertain. There are some groups of insects in which it is virtually impossible to secure reliable identifications at the present time. Yet progress is achieved by attempting the problems which are difficult, and in which much is yet obscure.

No other state south of the Potomac and Ohio rivers and east of the Mississippi, is engaged in a survey of this kind. Very few lists of insects, even in limited groups, have been published from any of the southeastern states—more from Florida than any other, and Florida is different from the other states in many ways.

We have had the generous help of specialists at the U. S. National Museum and elsewhere in the identification of our specimens and the workers within our own state have been able to identify a considerable number. Persons from other states who have collected within our borders have kindly furnished lists or even specimens. Such amateur collectors as are known to reside in the state have been solicited, and at this point we must acknowledge the numerous contributions to our records which have come from Rev. A. H. Manee of Southern Pines. Much helpful literature has been accumulated, and, working with a card-catalogue system we have been able to make what we believe to be a reasonably good start toward ascertaining what our insect fauna really is, and what it signifies in its relations to human welfare.

Our list includes only species known to occur within the state as confirmed by specimens or by presumably authentic published records. Perhaps three-fourths of them are represented in the state collections under our charge. The list is under continual revision including the insertion of additional species, and also occasional eliminations as these become necessary by changes in classification or by the detection of errors.

Table I shows the number of species of insects which we had on record as occurring in North Carolina at the close of 1914 and at close of each of the ten years since, showing also the number of additions to the list which were made in each year. Mr. Brimley came to this task toward the close of 1919; Mr. T. B. Mitchell, whose work has contributed

TABLE I

YEAR	ADDITIONS DURING YEAR	TOTAL NORTH CAROLINA INSECTS RECORDED AT END OF YEAR
1914		4,430 species
1915	267	4,697 species
1916	161	4,858 species
1917	82	4,940 species
1918	104	5,044 species
1919	201	5,245 species
1920	550	5,795 species
1921	574	6,369 species
1922	220	6,589 species
1923	231	6,820 species
1924	258	7,078 species
March 31, 1925	35	7,113 species

many records, came into the state work in 1920; and Mr. J. C. Crawford, whose work has helped materially, came on the scene early in 1923. The effect of the labors of these gentlemen can be noticed in the figures for the more recent years.

To the layman it might seem that with 4430 species of insects on record at close of 1914, additions to the list would be difficult to secure; likewise it would seem that with 5245 at the close of 1919, additions would come yet more slowly, yet 1920 and 1921 were our banner years of this ten-year period with more than a thousand species added during the two years. Nevertheless, the figures also show a steady accession of records in each year since 1921. Theoretically it is true, and it seems that it should show in practice, that the larger the list the fewer

the number awaiting record, and that progress would be slower with each succeeding year,—the fact that our rate of progress is still fairly high is one of our best evidences that we still have far to go, that the list is still far from complete.

In recent years much of our progress has been among insects of small size; naturally a greater percentage of our larger and conspicuous insects are on record, than of the smaller and inconspicuous ones. But the importance of an insect to human welfare is not dependent upon its size; *Trichogramma minutum* is a parasitic insect so small that we have reared three specimens to full maturity from inside a single insect-egg the size of a period in ordinary print, yet I venture the estimate that its beneficial activities in this state have been worth hundreds of thousands of dollars. There are whole families of insects which have considerable potential possibilities for harm, or good, of which we as yet know but little of the distribution and life-habits of the species, and these in turn, are held in subjection, in part at least, by the species of other families of insects which we know only in part as yet—"as through a glass, darkly." We are yet far, very far, from an adequate knowledge of some of our largest, most common, and most important insects, and this work is intended to include the recording of all species of insects, including those which may not now be known to be of "practical" importance. A person for whom I have great respect once said to me: "All truth is of value."

In connection with this survey of the species occurring within the state, we maintain a record of virtually all current complaints and inquiries about insects which have come to us from within the state since about 1900. The complaint records, for any species, can be compiled as for years, or months, or for crops. Thus we know that certain pests attract attention chiefly in certain months, not always throughout the year, nor always throughout the growing season of the crop,—we are thus able to specify with a considerable degree of accuracy the particular months in which the pest is likely to attract attention. Many of our insect pests are spasmodic, appearing in destructive numbers one year, and not attracting attention through several succeeding years; a compilation of these records show which have been the outstanding years for each pest, as reflected by our correspondence. They constitute entomological history.

We had not gone far in our Insect Survey before we felt the desirability of being able to compare our findings in Insects, with the known findings in other groups of animals. The appearance of the volumes "Fishes

of North Carolina," and "Birds of North Carolina," gave a groundwork for this comparative data, and the species recorded in both volumes were card-catalogued in much the same manner as our Insects and on the same standard type of card. When Mr. Brimley came into the state service he soon likewise card-catalogued the species of Batrachians, Reptiles and Mammals of the state which have been recorded in papers by himself or others. With the Vertebrates thus on record, and the Insects in full swing, it was merely an incident to include the Invertebrates other than Insects. Here there is a scarcity of published records and few workers within the state, and also our own efforts are primarily with the Insects; however, these other groups of Invertebrates have been card-catalogued in such manner that additions can readily be made as they come to attention. In this incidental phase of the Survey work we are of course under large obligations to the workers in these other groups.

What is the present known status of the Animal Kingdom in North Carolina? Which great zoological groups have shown the greatest elasticity, adaptability, and fecundity,—biologically, which have been the most "successful" groups?

We now present a synopsis of the Animal Life of the State as known to us March 31, 1925, the Insects along with the others, in approximately the accepted zoological sequence.

ANIMAL LIFE OF NORTH CAROLINA (MARCH 31ST, 1925)

PROTOZOA—(One-celled animals)		134 species
PORIFERA—(Sponges, etc.)		19 species
COELENTERATA—(Jelly-fishes and allies)		66 species
VERMES—(Unsegmented worms)		83 species
ANNELIDA—(Segmented worms)		83 species
ECHINODERMATA—(Star-fishes and allies)		23 species
MOLLUSCA—(Snails, clams, oysters, "shell-fish," etc)		381 species
ARTHROPODA—(Insects, and allies)		7,586 species
CRUSTACEA (Crabs, Crayfish, etc.)	236 species	
MYRIAPODA (Centipedes, millipedes, etc.)	39 species	
ARACHNIDA (Spiders and allies)	198 species	
INSECTA (True Insects)	7,113 species	
PROTOCHORDATA (Forerunners of Vertebrates)		8 species
CHORDATA (Vertebrates)		935 species
FISHES	378 species	
AMPHIBIANS (Salamanders, frogs, and toads)	56 species	
REPTILES (Snakes, turtles, lizards, alligator)	67 species	

BIRDS	349 species	
MAMMALS (including Man)	85 species	
Total Animals		9,318 species
All animals *except Insects*	2,205 species	
Insects *only*	7,113 species	

Insects comprise 76 per cent of the total.

Any well-informed person can say that insects are "very numerous," and perhaps that they are "very important," and may even be familiar with the trite statement that in number of species they constitute "about four-fifths of the animal kingdom;" but here we have an actual record, very close to accuracy so far as it goes, which shows a little more than three-fourths of the recorded animal species of North Carolina to be insects.

In the Vertebrates relatively few additions to this list can be expected, and those chiefly among the Fishes. In the Invertebrates other than Insects there are undoubtedly many to be added, and in the Insects themselves we know that the field is still fertile. With the large preponderance already attained by the Insects, and considering the rate at which we are adding, it is reasonable to believe that in the additions of the future the Insects will hold their own or perhaps increase their lead, perhaps attaining 80 per cent of the total, the traditional four-fifths of the entire number of animals.

The workings of this Animal-complex,—the inter-reactions among the numerous groups of Insects and the reactions between the Insects and the Birds, the Insects and the Fishes, etc., would furnish material for several hundreds of papers the length of this one. This paper merely sketches the progress to the present time.

The former and present Assistants of this office whose activities have resulted in the most noteworthy contributions to the Insect Survey records are: Prof. Z. P. Metcalf, now of N. C. State College; Prof. C. L. Metcalf, now of University of Illinois; Mr. M. R. Smith now of Mississippi State Plant Board; Dr. R. W. Leiby; Mr. T. B. Mitchell; and Mr. J. C. Crawford. The work of Mr. C. S. Brimley and the writer has already been indicated.

STATE DEPARTMENT OF AGRICULTURE,
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IRON COLORATION IN ROCKS AND MINERALS

By Gerald R. MacCarthy

It has long been a dogma of geology that the green coloration of certain iron-bearing rocks and minerals is caused by the presence of ferrous iron, while it is well known that the browns, reds and yellows of our common soils are a result of the presence of ferric iron. It also appears that certain blues and bluish grays are equally caused by the presence of ferruginous compounds, although this fact is usually passed over in silence.

As long ago as 1898 Spring (1) called attention to the fact that freshly prepared artificial ferrous silicate is always colorless provided that care has been taken to avoid any oxidation during its preparation, and only assumes a blue or green tint after exposure to oxidizing influences. In 1918 Watson and Wherry (2) showed that the colorless iron phosphate vivianite turned blue only when partially oxidized, and suggested that this change was due to the presence of both ferric and ferrous iron. They also noted that other iron compounds containing both the ferric and the ferrous molecule are blue, among them "Prussian blue" and Turnbull's blue.

In the course of an investigation of the rôle played by iron as a geological coloring agent, the writer had occasion to draw up a table giving the ferrous-ferric ratios obtained from the analyses of over a hundred rocks and soils whose color was due to iron-bearing compounds. When these ratios were arranged in order, beginning with the least ferrous, the following relationships were brought out:

For ratios between 0.000 and 0.550 reds, yellows, and browns alone were met with; for ratios between 0.550 and 0.675 purples and dark blues are found almost without exception; from 0.675 to 1.35 blues predominate. As the ratio of ferrous to ferric iron increases beyond this point we meet with a diminishing number of blues, a total lack of purples, reds, yellows, and browns, and a growing number of greens and blacks.

Spring, as cited above, made artificial ferrous silicates which were always colorless when fresh, but which passed from colorless to blue, from blue to green, and from green to yellow when allowed to oxidize. This he rightly interprets as an effect of increasing oxidation. The pure ferrous salt would then be colorless, a ferroso-ferric compound blue

and the end product—pure ferric silicate—yellow. An examination of the ratios given above, derived by dividing the ferrous iron content by the ferric iron content of a series of sedimentary rocks and soils, will show that the purples lie between the reds and blues, and, since purple may be formed by mixing blue and red pigments, it would seem that in this case it is produced by a mixture of the red ferric with the blue ferroso-ferric molecule. Red ferric compounds pass over into yellow on dilution, as may be seen by making solutions of ferric hydroxide of varying concentrations, and since the end point of the color changes of Spring's silicates was a yellow, it would likewise seem that the green was produced by an admixture of the blue ferroso-ferric molecule with a yellow ferric molecule.

As to the blacks, which appear abundantly only when the proportion of ferrous iron is high, nothing definite can as yet be said. The black coloration of many of the shales and clays examined was doubtless due to the presence of carbonaceous matter which, by partial reduction of the iron, would at the same time lead to a preponderance of the ferrous molecule. Yet several minerals, such as magnetite, which have ferrous-ferric ratios of about 0.450 are also black. A possible explanation is found in the fact that they are anhydrous, which taken in connection with the fact that all blue iron compounds which the writer has been able to discover are hydrous, would suggest that perhaps the blue ferroso-ferric color only appears in the presence of water of composition. The blackening of certain red sandstones where they have come in contact with diabase intrusions also points in the same direction, since they have been at the same time reduced and dehydrated.

Since the blue color appears with great suddenness at about 0.675 it may be that the blue ferroso-ferric compounds will only form when the proportion of ferrous iron exceeds a certain definite limit. This matter is now being investigated, and as yet no conclusive results have been obtained, although the limit is tentatively placed at $3FeO:2Fe_2O_3$. This lower limit is well marked, although any upper limit must of necessity be illdefined, since an admixture of the colorless ferrous molecule will not affect the color except by way of dilution.

CONCLUSIONS

A. Ferrous compounds occurring in soils and sedimentary rocks are colorless or nearly so.

B. Ferric compounds are reddish brown, red, or yellow according to concentration.

C. Hydrous ferroso-ferric compounds tend to be blue.

D. A mixture of hydrous ferroso-ferric compounds (blue) with large amounts of ferric compounds (red) gives a purple coloration.

E. A mixture of hydrous ferroso-ferric (blue) compounds with a smaller amount of ferric compounds (yellow) gives a green coloration.

F. Pure ferrous compounds, being colorless, may be mixed in any proportion with any of the above, since, being colorless, they can affect the color only by dilution.

UNIVERSITY OF NORTH CAROLINA,
CHAPEL HILL, N. C.

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TWO RARE TYPES OF ABNORMALITY IN COTTON SEEDS[1]

By S. G. Lehman

Plate 7

The writer has had occasion in the past few years to observe the germination of a great many cotton seeds. On two occasions, single seeds were found whose appearance at the time of germination indicated embryological situations which are unusual for seeds in general and very rare for cotton seeds in particular. In the cotton seed, as it is normally constituted, the cotyledons of the embryo are thin, broadly expanded organs which are folded in such a way as to completely envelope the straight radicle. The embryo together with its protecting structure, the seedcoat, is so shaped that the seed is more or less oval, being large and rounded at the chalazal end and small and somewhat pointed at the micropylar end. The radicle is so oriented as to lie in the axis of the seed which extends through the micropyle and the center of the chalazal region, and the hypocotyl and root-tip are directed toward the micropyle. In germination, the swelling of the embryo breaks open the seed coat at the micropylar end and the smaller, more or less pointed end of the folded cotyledons enveloping the hypocotyl and root-tip often extends beyond the seed coat at this place. The hypocotyl and root then grow directly forward and, without bending or curvature, out from between the folded cotyledons. Later, the cotyledons unfold, withdrawing from the seedcoat at the same time.

In the case of the first type of abnormality observed, the observer's interest was aroused by the fact that the hypocotyl and root-tip had not grown directly forward and out from the smaller region of the enveloping cotyledons, as is the habit in normal seeds, but appeared, while still partially covered by the seedcoat, to have emerged from the side or opposite end of the folded cotyledons (fig. 1). After the seedling had been photographed, the seedcoat was carefully removed, whereupon it was seen that the embryo occupied a position within the seedcoat just the reverse of the normal in orientation and that as a consequence the hypocotyl and root-tip had actually elongated in the direction of the

[1] All citations are from Coulter and Chamberlain. Morphology of Angiosperms, New York, 1912.

chalazal end of the seed and had been forced to bend through an angle of about 180 degrees in order to escape from the seedcoat (fig. 2). The bending occurred in the hypocotyl and not at the point of union of cotyledons and hypocotyl. Some departure from the normal vernation of the cotyledons was apparent, but this variation appeared to result from rather than to constitute an explanation of the reversal of the position of the embryo.

The cause of the reversed orientation of the embryo in the case of this seed is of course conjectural. It may be suggested, however, that this situation may have arisen because of the failure of the egg apparatus, usually located at the micropylar end of the embryo sac, to function, either through lack of fertilization or other hinderance, and the subsequent development of one of the antipodal cells apogamously or after fertilization by one of the male nuclei. The reversed orientation indicates that the embryo developed from an antipodal cell. Both Tretjakow and Hegelmaier observed and figured immature embryos arising from antipodal cells in the embryo sac of *Allium odorum*.

The second type of abnormality described herein is a case of polyembryony. Attention was drawn to this particular seed by the fact that two roots were issuing from the same seed (fig. 3). One of these was large and vigorous, the other comparatively small and weak. After photographing the seed, the coat and the surrounding remnant of the endosperm were removed. Both roots were found to come from within the enveloping cotyledons of the larger of the two embryos. These cotyledons were carefully unfolded whereupon a second pair of small cotyledons, attached in a normal manner to the smaller of the two radicles, was found (fig. 4). These smaller cotyledons were folded around the hypocotyl of the larger embryo close to the point of attachment of the cotyledons of the latter. Apparently, in the ungerminated seed, the cotyledons of the smaller embryo partly enveloped the hypocotyl of the larger embryo, while, at the same time, the cotyledons of the latter, in turn, enveloped the whole of the smaller embryo. Moreover, the thin remnant of one and the same endosperm completely enclosed both embryos.

It is reasonable to assume that the larger and more vigorous of the twin embryos described above came from the fertilized egg. The origin of the other is not so obvious. In certain plants, embryos are known to develop vegetatively from sporophytic cells of the ovule external to the embryo sac, as from nucellar or integumentary tissue; but such an interpretation of the situation described above seems too

far afield to be worthy of more than mention. The intimate juxtaposition and similar normal orientation of the two embryos seem to indicate that both originated from cells within the embryo sac. Likewise, the same considerations appear to eliminate the antipodals and to designate the cells of the egg apparatus as the direct or indirect origin of the second and smaller embryo. In *Erythronium americanum* and *Tulipa Gesneriana* of the Liliaceae and *Limnocharis emarginata* of the Alismaceae multiple embryos arise by budding of a massive suspensor, and in *Mimosa Denhartii*, *Naias major* and *Taraxicum officinale* embryos develop from synergids. In some plants additional embryos are reported to arise by still other means, *i.e.*, by the splitting of the embryo derived from the egg, by the normal occurrence of two eggs, and from endosperm cells. Development from any of these sources might, with more or less question, be cited to explain the presence of the second embryo in the cotton seed described herein. However, its exact origin must remain in doubt. Still, it seems not unreasonable to assume that the two embryos developed not from cells external to the embryo sac but from truly gametophytic cells within the embryo sac. In any event, the embryological situation herein described represents a rare case of polyembryony in the cotton plant.

EXPLANATION OF PLATE 7

Fig. 1. A cotton seed containing an embryo in reversed position. The radicle emerging at the mycropylar end of the broken seed coat actually started growth toward the chalazal end and was forced to reverse its direction of growth in order to escape from the seed coat.

Fig. 2. Embryo and seed coat of seed shown in figure 1 after removal of seed coal. Note the bend in the hypocotyl.

Fig. 3. A cotton seed from which two radicles have emerged.

Fig. 4. Two embryos taken from the seed shown in figure 3.

PLATE 7

Fig. 1

Fig. 2

Fig. 3

Fig. 4

A NEW DIOECIOUS SPECIES OF CHOANEPHORA

By J. N. Couch

Plates 8–11

The genus *Choanephora*, composed of a very small group of plants, occupies an exceptionally interesting place in the Zygomycetes for three reasons: first, it is the only known genus of that order in which both sporangia and conidia are present; second, it contains the only species in the order which are parasitic on flowering plants; and third, although sexual fruits have been reported in all of the species, no one has as yet accounted for their occurrence.

Except for the work of Thaxter ('03) Moeller ('01) and Wolf ('17) these fungi have escaped the study of botanists in the western hemisphere.[1] Wolf, who first reported the zygospores of *C. cucurbitarum*, states in regard to their formation, "All attempts to determine the conditions necessary for zygospore formation have been futile. Curiously, no zygospores appeared in subcultures from cultures in which zygospores were present; nor have they ever been noted in culture except when the conidia for making these cultures were taken directly from the host plant." Dastur ('20) reports a similar condition in *C. cucurbitarum* on Chillies (*Capsicum* spp.) in India. Palm and Jochems ('24), in describing a disease caused by the same fungus on *Amaranthus* from Sumatra, report that they obtained no zygospores. Cunningham ('78 and '95) described two species from India, one, *C. infundibulifera* ('78) collected on the fading petals of *Hibiscus rosa-sinensis*, the other *C. Simsonii* ('95) found parasitizing the leaves and shoots of *Ipomoea rubro-caerulea*. He found in both of these plants conidia, sporangia, gemmae, and zygospores. In regard to the occurrence of zygospores he states, "There is nothing to indicate what is the essential determinant of the appearance of zygosporic fructification, for, in two cultivations conducted side by side in portions of one and the same specimen of a medium, zygospores may be entirely absent in one and almost entirely replace sporangia in the other."

In the present paper a dioecious species of *Choanephora*, which seems

[1] Since this paper went to press, the writer has been informed by Dr. Blakeslee that *Choanephora cucurbitatum*, which he has had in culture for some time, is dioecious.

to be quite distinct from the other species is described. The work was done under the supervision of Dr. W. C. Coker, to whom the writer wishes to express his sincerest gratitude for helpful advice and criticism.

The species here described first appeared on corn meal agar in a Petri dish in the laboratory at Chapel Hill last August, growing with material of other fungi collected in Florida. Whether it really came from Florida is of course uncertain. In the first cultures conidiophores and sporangia appeared in great abundance but no zygospores. It was suspected, therefore, that the mold was dioecious. This strain was purified by the isolation of a single conidiospore by the dilution method, sporangia and conidiophores still appearing in great abundance but no zygotes. Blossoms of *Hibiscus syriacus* and of squash were then collected and put in damp chambers in the hope that the opposite sexual strain of the mold would appear. On the second morning a luxuriant growth of the fine cottony threads with an abundance of conspicuous upright conidiophores appeared on the *Hibiscus* blossoms. In sporangic and conidiophoric characters the two strains agreed perfectly. A single spore culture was then made of the second strain. The two strains when kept separate were sexually sterile, *i.e.*, produced no zygotes, and remain so up until the present time (March 18, 1925). The two strains were then grown together on the same Petri dish and where the threads of the two opposite strains intermingled a dense line of zygotes was formed (plate 9). In cases in which the origin of the suspensors could be traced they were seen to arise from separate hyphae.

Some experiments were conducted in an effort to determine the influence of external factors on the formation of zygotes. Eight crosses were made on corn meal agar made up according to our standard formula (4 teaspoons of corn meal in 1 liter of water heated over water bath 1 hour. Filter. To filtrate add 12 grams agar. Autoclave 15 to 30 minutes 10 to 15° pressure) and very few zygotes were formed. Conidia and sporangia however were produced in great abundance. By further experimentation it was found that if the amount of corn meal is doubled or trebled the number of zygotes is greatly increased.

No elaborate attempt has been made to determine the effect of temperature on sexual reproduction but the following description of events as they occurred in the laboratory would seem to show that the effect of temperature on sexual reproduction is quite marked. In practically all of the numerous crosses made between August and the middle of December zygotes appeared in more or less abundance, the

number apparently depending upon the concentration of food. Just before the Christmas holidays the temperature dropped to several degrees below freezing and continued low for several days, resulting in a low temperature in the laboratory (about 8°C). None of the crosses made during this cold period produced any zygotes, and what is even more striking the two strains seemed to have lost their power to react sexually during this cold weather; for in none of the numerous crosses made since have any zygotes appeared. Whether the loss of the power to react sexually was due to cold weather, or to the loss of one of the strains in transferring cultures, is in doubt, but the writer is inclined to the latter belief.

It may be concluded therefore that although the plant is dioecious, external factors play an important part in sexual reproduction. The exact nature of these factors, however, is not clear at present

The plant is named *Choanephora conjuncta* because it combines certain characteristics of each of the other species. The following description is made from cultures growing on corn meal agar.

Choanephora conjuncta n. sp.

Vegetative hyphae strongly developed, the nutritive hyphae growing usually just beneath the surface of the agar, 6–16μ thick; aerial hyphae developed abundantly under conditions of bountiful moisture, forming a dense cottony mass over the surface of the agar and quite often completely filling the dish; sinuous, considerably branched, aseptate, hyaline; densely filled with protoplasm in the young condition, becoming much vacuolate. Conidiophores upright, 2–5 mm. high; the head simple, bearing the spores directly or, as is much oftener the case, giving rise to numerous (2–28) branchlets which become distally swollen into subspherical or oval-shaped secondary heads on the distal half or two-thirds of which are borne the numerous conidia. The proximal half of the secondary head and the stalk become indurated upon aging while the outer half, to which the spores are attached, shrivels and falls away, leaving the remnant of the secondary heads funnel-shaped. In the same culture with the normal and more numerous type of conidiophore depauperate ones may be formed bearing only one or two conidia, the walls of which are usually sculptured like sporangial walls. Conidia formed at night and maturing during the early hours of daylight, pure white at first, then light purplish brown and finally appearing purplish black; quite variable in size and shape, usually about 14.8 x 18.5μ, but varying between 9–31 x 12–34μ; subspherical to ovoid, usually thickest in the distal half, furnished with a distinct hyaline mucro; the surface smooth externally but the inner wall apparently minutely punctate; light brown with a tint of purple

under the microscope; germinating in position almost immediately upon being formed. Sporangia formed later than the conidia, and in fewer numbers, borne on rather short recurved stalks, very variable in size and the number of spores contained; 20–100μ thick, spherical, containing 2 to 30 or even more spores; opening by a longitudinal split into two halves; wall covered with rather small angular granules not dissolving in water; columella spherical to conic, usually without a collar, very variable in size, not rarely partially or completely collapsing. Sporangiospores usually sub-elliptic, more or less pointed at both ends, 7.4–11 x 11–21μ, quite variable in shape, not rarely inequilateral, very peculiar in having numerous, long, hyaline threads protruding from the angles and with which they are attached to the sporangial wall, wall longitudinally striate; spores sprouting readily but not so soon after formation as the conidia. Under adverse conditions of culture gemmae are usually formed. These are borne on the ends of small rather delicate threads, are oval in shape, smooth walled and about 20 x 30μ. Zygospores formed only when two opposite strains are grown in contact; formed within the substratum; progametes usually isogamous, coiling about each other more or less, and often so much so as to form a very elaborate complication of hyphae at the base of the zygote; mature zygote spherical, subspherical, or bent elliptic; 28–66μ thick, with a conspicuous, spherical, oil drop 25–40μ thick; wall 3–5.8μ thick, striated; brown with an olive tint when first mature, becoming golden brown upon aging.

Collected twice at Chapel Hill on the fading flowers of *Hibiscus syriacus* (*Althea*).

Of the three previously described species of *Choanephora*, one, *C. cucurbitarum*, is of wide distribution, having been described from the United States, Brazil, India, and Sumatra. In our country it has been reported from South Carolina by Berkeley and Ravenel as *Rhopalomyces cucurbitarum* B. & Rav., from New York by Peck and from Ohio by Morgan under the same name; from New England and Florida by Thaxter and from North Carolina by Wolf as *Choanephora cucurbitarum*. The other two, *C. infundibulifera* and *C. Simsonii*, have been reported only from East India.

In certain respects these three previously described species strikingly agree with each other and with the Chapel Hill plant. It seems best, therefore, for the sake of comparison to briefly state the most important characteristics of each of the three plants.

Choanephora cucurbitarum parasitizes summer squashes and also grows on the flowers of althea, cucumber, okra, cotton, and other malvaceous plants. After the conidiosphores mature the secondary

PLATE 8

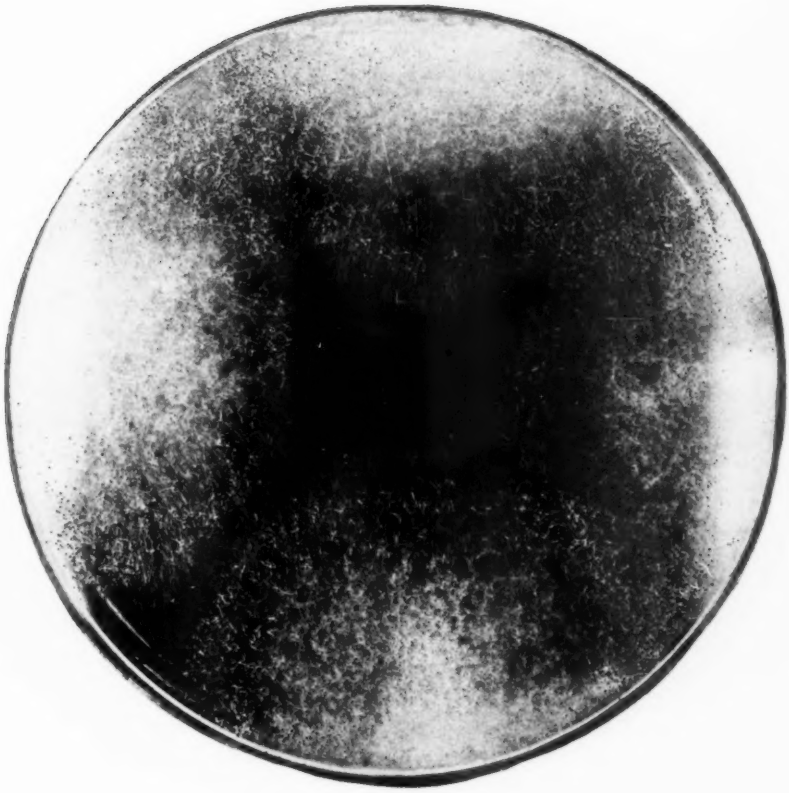

PLATE 8

Choanephora conjuncta, strain 2. Slightly enlarged. Showing habit on agar, and conidiophores.

PLATE 9

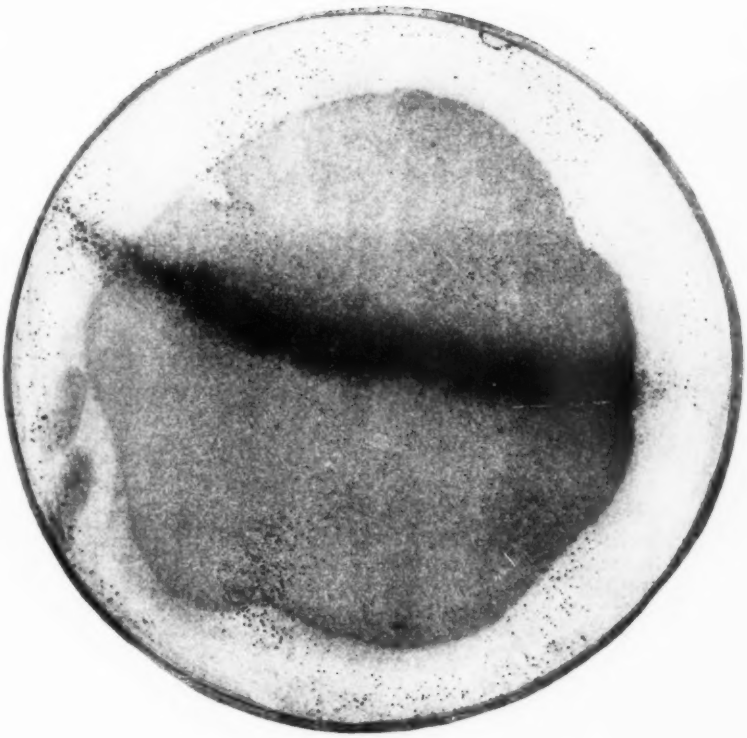

PLATE 9

Choanephora conjuncta. Cross between strain 1 (below) and strain 2 (above), showing a dense black region of zygotes where the two strains meet. The other black dots are conidiophores.

heads fall off, leaving the primary head with holes in it. The conidia are fusiform with a longitudinally striate membrane. The sporangia are small to large, containing a few to many usually fusiform, smooth spores with threadlike appendages. The zygotes are smooth and with but few hyphae at their base. The Chapel Hill species agrees with *C. cucurbitarum* only in the occasional habit the latter plant has of growing on the fading flowers of *Hibiscus*. Numerous efforts have been made to induce the present species to grow as a parasite on the flowers and young fruits of squash, one of the natural habitats of *C. cucurbitarum*, but without success. In conidiophoric, sporangial, and zygosporic characters the two plants are quite distinct.

Choanephora infundibulifera has been found as a saprophyte on the fading flowers of *Hibiscus*. The secondary heads of the conidiophores are round at first but become funnel-shaped by the falling away of the distal half after the spores mature. The conidia are ovoid and smooth. The sporangia are small, containing only a few, 6–8 elliptic (Cunningham '78 says elliptic but his figures show ovoid spores), smooth spores without appendages. The zygotes are smooth and with many hyphae at their base. The contents of the zygote shrinks away from the wall giving the appearance of an egg within an oogonium.

The other Indian plant, *C. Simsonii*, parasitizes the leaves and young shoots of *Ipomoea* and the flowers of *Zinnia* and will also grow as a saprophyte in infusions of the leaves of *Ipomoea* or of the flowers of *Zinnia* or *Hibiscus*. The conidiophores are abundant when the plant grows as a parasite but rarely make their appearance in artificial cultures in nutritive infusions and when they do are feebly developed in a peronosporoid fashion. In this species the secondary heads are abruptly truncate, bearing on the truncated extremity the fusiform, finely striate conidia. The sporangia are large and are developed in great abundance when cultivated in vegetable infusions. The stalk is abruptly flexed immediately beneath the sporangium. The sporangia dehisce in valvular fashion and the membrane is finely tuberculate. The fusiform spores are finely striate, with threadlike appendages. The zygotes are striate and are nearly black.

The Chapel Hill plant combines in a very remarkable way some of the characteristics of both of the Indian plants. With *C. infundibulifera* it agrees in habitat and in conidiophoric characters but can readily be distinguished from that plant by the sporangial and zygosporic characters. With the other Indian species, *C. Simsonii*, it agrees in sporangial and zygosporic characters but can easily be separated from that

plant by the conidiophoric characters. The parasitic habit of *C. Simsonii* on *Ipomoea* is also a serious discrepancy. Several attempts have been made to induce the Chapel Hill plant to parasitize the flowers and young shoots of *Ipomoea* but without any success. In infusions of morning glory flowers the growth was poor, and only a few conidia (all of the normal type) were produced and no sporangia. In infusions of the leaves the growth was fair and a good many conidia and sporangia were formed. The results here obtained are exactly the opposite of those obtained by Cunningham with *C. Simsonii* when cultured in vegetable infusions, the latter producing many large sporangia and only a few depauperate conidiophores.

In the development of the fungus there are several points worthy of particular notice.

This fungus when growing on nutrient agar has the appearance under the microscope of one fungus parasitizing another. Indeed when the plant first appeared in the laboratory it was thought that the conidia belonged to one plant and the sporangia to another and that one of the plants was parasitic on the other. Repeated efforts were made to secure pure cultures of both the conidia bearing and the sporangia bearing plants, but in cultures from a single conidium both conidiophores and sporangia appeared, as was also the case in cultures from a single sporangiospore.

This very remarkable parasitic appearance is caused by the peculiar habit the aerial hyphae have of twining tightly about the stalk of the conidiophores so as, in rare instances, to cause the complete abortion of the latter. The hyphae which come from the germinating conidia quite often twine around the parent conidiophore stalk until they reach the substratum or pass on to other conidiophore stalks.

The conidiophores are formed in maximum abundance when the nutrient agar is made up with a relatively high per cent of agar for the amount of water (14 grams agar to 1 liter of water); and conversely if a small amount of agar is used (10 grams to 1 liter of water) very few or no conidiophores are formed and the aerial mycelium is developed in great abundance. If the Petri dish top from such a culture as the latter is removed and the culture is put in a large chamber, conidiophores will be formed in considerable abundance over night. Or if a large square of nutrient agar containing hyphae which have already borne a crop of conidiophores is cut out and kept in a fresh Petri dish over night a considerable crop of conidiophores will be formed. If, however,

the culture is left completely uncovered so as to be exposed to the dry atmospheric conditions of the laboratory, no conidiophores at all will be formed. These experiments, repeated several times with the same results, show that the production of conidia is favored by a humid atmosphere.

The influence of light on the formation of the conidia is very marked in this species. As has been noted above, the fungus when subjected to the ordinary illumination of alternating daylight and darkness forms conidia at night which mature during the early hours of daylight. If, however, the fungus is kept in constant darkness, the formation of conidia is totally inhibited. The effect of light on conidia formation has been studied by numerous observers and numerous cases have been reported where alternating light and darkness produce zonation. (For bibliography see Bisby: Zonation in cultures of *Fusarium*. Mycologia **17**:89. 1925.)

In development the zygote seems to resemble the Piptocephalidaceae more than any other of the Zygomycetes. In the former group the two gametes are curved and so disposed that the pair has very nearly the form of a stretched bow. The surface of union lies in the apex of the bow. The zygote arises as an outgrowth on the convex side of the bow at the place of coalescence of the two gametes. "When it has reached the limit of its growth, it is delimited by a partition wall from each limb of the bow and becomes a nearly spherical zygospore; it may at least be so called for the sake of clearness and simplicity, though it is plain that it is not the strict morphological equivalent of the zygospore of the first case (*Rhizopus nigricans*)" (de Bary Comparative Morphology and Biology of Fungi, etc. p. 149, 1887).

In *Choanephora conjuncta* the gametes are so disposed as to form a bow (plate 11, figs. 8–12) and the basal hyphae from which these arise are much coiled about each other. Instead, however, of the zygote arising as an outgrowth from the convex side of the bow as in *Piptocephalis*, each of the progametes in *Choanephora* divides into two cells, the two adjacent cells from the opposite threads becoming the gametes and coalescing. The young zygote now swells, and as it grows the two supporting cells become empty as if nourishing it. Actual passage of material was not observed. Thus in *Choanephora* as in *Piptocephalis* the spherical zygospore is placed at the apex of the bow formed by the pair of suspensors and each suspensor is cut off from the hyphae by transverse walls.

SUMMARY

A new dioecious species of *Choanephora* with saprophytic habit is described. The production of zygotes in this species seems to be conditioned primarily by the inherent nature of the individual strains, but external factors seem to play an important part. The formation of conidia is favored by a relatively humid atmosphere, a dry atmosphere or too much moisture inhibiting their formation. In development the zygote seems to resemble the Piptocephalidaceae more than any other family of the order.

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EXPLANATION OF PLATES

PLATE 10

Fig. 1. Typical conidiophore showing eleven secondary heads with spores. × 180.
Fig. 2. Conidiophore with two secondary heads, showing the spores covering only the distal two thirds or half of the heads. × 180.
Fig. 3. Conidiophore with two secondary heads, showing the sterigmata on which in a few cases spores are forming. × 413.
Fig. 4. Conidiophore with one head on which the spores are forming directly. × 180.
Figs. 5 and 6. Depauperate conidiophores, the conidia with roughened walls resembling sporangia. × 413.
Fig. 7. Conidium sprouting almost immediately after being formed. × 733.
Fig. 8. Conidium sprouting after several days rest showing crystals on the walls. × 733.
Fig. 9. Section of thread showing vacuoles. × 733.
Fig. 10. Surface of thread. × 733.
Fig. 11. Gemma. × 413.
Fig. 12. Conidia. × 900.
Fig. 13. Conidiophore head after the spores have fallen off showing the funnel shaped remains of the secondary heads. × 413.
Fig. 14. A secondary head from which spores have fallen, showing the shrivelling distal half. × 413.
Fig. 15. A conidiophore head from which the secondary stalks have been rather abruptly broken off. × 413.

PLATE 11

Fig. 1. Sporangiophore. × 180.
Fig. 2. Depauperate sporangiophore. × 180.
Figs. 3 and 4. Columellae. × 413.
Fig. 5. Sporangium showing typical mode of opening. × 413.
Fig. 6. Sporangiospores showing longitudinally striate wall, and peculiar delicate hair-like appendages. One of the spores is sprouting. × 900.
Fig. 7. Early stage in the development of the zygote. The gametes are cut off and a cross wall separates the suspensor from the thread. Note the extra and aborted progamete with an apparent hole in its distal end. × 413.
Fig. 8. Later stage in the development of the zygote. × 413.
Fig. 9. Gametes in a late stage of fusion, the wall between them nearly gone. Gametes with a large central vacuole. Cells beneath the gametes densely filled with protoplasm. × 413.

Fig. 10. Zygote rounding up; wall thickening, oil collecting into large drops. The cells beneath the zygote nearly empty, the contents having passed into the zygote. × 413. Figures 9 and 10 were drawn from the same zygote with about 18 hours intervening.

Fig. 11. Typical ripe zygote with distinctly striated wall. × 413.

Fig. 12. Irregularly shaped zygote. × 413.

PLATE 10

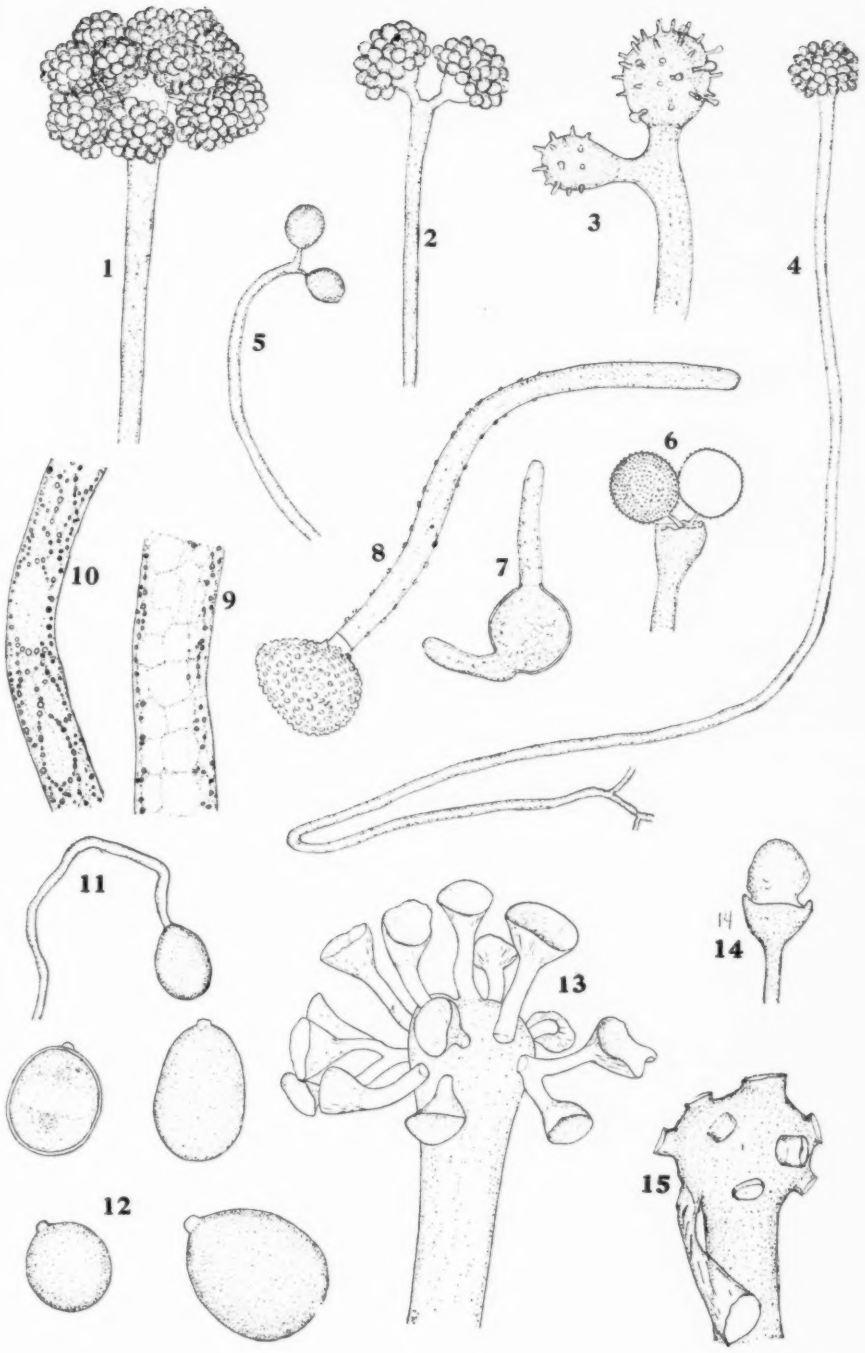
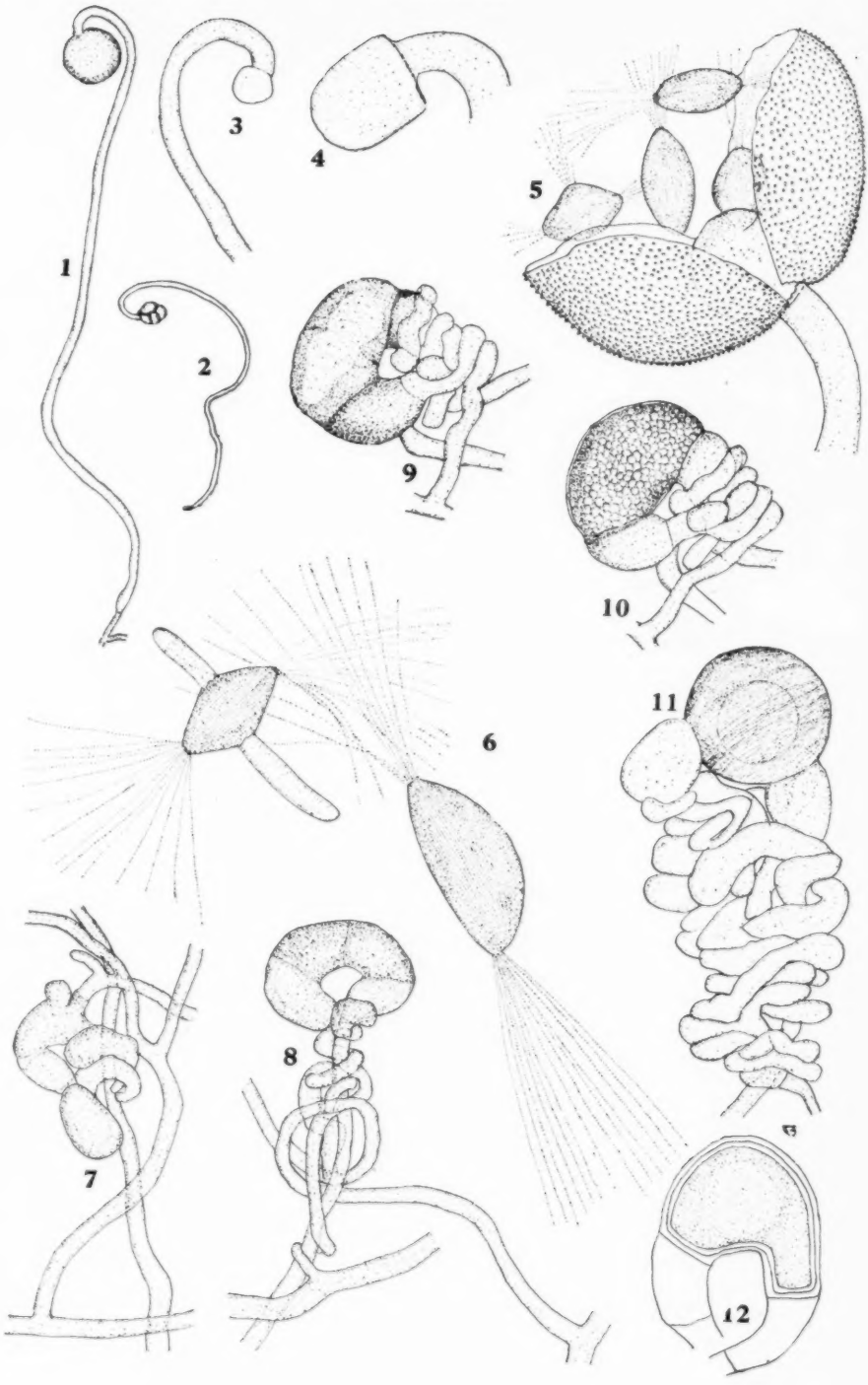


PLATE 11



A STUDY OF THE WATER MOLDS AND PYTHIUMS OCCURRING IN THE SOILS OF CHAPEL HILL[1]

By James Vernon Harvey

Plates 12–19

During the past few months the writer has found for the first time that many of the typically aquatic fungi occur in the soil. Species of *Pythium* have long been known to lead a terrestrial life, and Butler (1) has more recently obtained many of them from earth. Except for two species of *Aphanomyces* parasitic on roots of beets and garden peas (5, 6), no one, so far as the writer has been able to find, has made mention of the isolation of the true water molds (Saprolegniaceae) from the soil. Aside from the higher forms, the fungi so far reported from the soil have consisted largely of the ascomycetous and zygomycetous molds (3, 4, 7) and of *Fungi imperfecti*.

In this paper the writer gives an account of results obtained after a few months' study of the aquatic fungi found in the soils of Chapel Hill. This work was done in the laboratory of the Department of Botany of the University of North Carolina under the direction of Dr. W. C. Coker, to whom the writer expresses his sincere appreciation for helpful criticism and advice. The writer wishes to express his appreciation to Dr. J. N. Couch for timely suggestions throughout the work. Valuable help was received also from Dr. H. R. Totten in making microphotographs.

Methods of Collection and Culture

To an extent the writer followed the methods used by Butler (1) in his collecting of soils to obtain *Pythium* species. Butler's method was to secure garden soils from the neighborhood of plant roots, at a depth of 6 inches below the surface of the ground. Over this was poured a film of tap-water, in which were floated particles of vegetable and animal matter as substrata.

Our procedure was as follows: In order to get collections as free as possible from outside contamination, sterile collecting bottles of 100 cc.

[1] This paper is a thesis submitted to the faculty of the University of North Carolina in partial fulfillment of the requirements for the degree of Master of Arts in the Department of Botany.

size were used. Various soils were taken at various places, two or three collections being made at each place, at an average depth of 2–12 inches. At times when trying for greater depths, soils were secured from the face of a fresh excavation for the new Methodist church in Chapel Hill, the dirt being taken at depths of 6–12 inches inward from the perpendicular surface. In this manner the soil was obtained to a vertical depth of 72 inches. In digging, care was taken to get a fairly large amount of dirt on the tip of a trowel from the depth desired. From this mass a few cubic centimeters of earth were taken from near the center.

The bottles were labelled and brought back to the laboratory and the contents of each bottle, about 10 cc., was spread out in a sterile petri dish and enough autoclaved tap-water poured into the dish that substrata could rest on the soil and at the same time be partly exposed to the air. Boiled hemp seed, corn grain and rye proved to be the best vegetable substrata, while termites killed and preserved in alcohol and soaked in sterile water offered good animal substrata. Among the few kinds of agar media used, corn meal agar proved to be the one best suited to grow "stock" cultures on. All the plants grew best on hemp seed.

From five to eight days later a faint halo of fungal threads would, as a rule, be observed on the substrata. The cultures would be transferred to a clean dish and washed with a stream of water from a wash bottle to remove soil particles. From this beginning pure cultures were obtained by the usual methods.

Wherever possible a single spore culture was made for each plant. A drop of water containing spores from a discharging sporangium would be taken from water cultures in a loop at the end of a platinum wire and spread over a thin, transparent agar plate. After a few hours a block of agar containing a sprouting spore would be cut out and transferred to a second plate. After the second plate became inoculated blocks of agar containing mycelium were placed in a petri dish. On each block a bit of substratum, usually a bit of hemp seed, was placed, and a little sterile water added to each dish. After one day, as a rule, the substratum would be surrounded by a healthy growth of the plant mycelium.

Collection Data and Description of New Species

The work of collecting soils was begun with the intention of working up a report on the *Pythiums* found around Chapel Hill, but upon dis-

covery that certain species of the *Saprolegniaceae* were abundant in the soils, attention was shifted largely to that family.

In the early fall of 1924, upon making a few collections and placing substrata thereon, as described above, the writer observed about a week later a hardy growth, which appeared to the naked eye a typical water mold. A microscopic examination disclosed the fact that the plant was *Thraustotheca clavata*. Thinking perhaps that this form may have been secured by collecting in unsterile bottles, greater care was taken to use sterile bottles in making further collections. This time *Thraustotheca* was not found, but *Saprolegnia ferax*, *Achlya caroliniana* and *A. flagellata* appeared. This was an impetus to isolate as many species of the *Saprolegniaceae* as possible and at the same time to work out, if possible, the ecological distribution of the water molds of the soil. With this in view, soils were collected from hilltop, hillside, and hollow, all types of soil, such as loam, humus, sand, clay, sandy loam, sandy humus, sandy clay, and iron being taken. Earth was taken from around the roots of various plants, pine, oak, grasses, corn, cotton, etc.

It is strikingly noticeable that only one species of *Saprolegnia*, *S. ferax*, occurred in any of the 200 collections, though a number of other species of *Saprolegnia* are common in water here. *Achlya caroliniana* and *A. flagellata* were found often. *Achlya hypogyna* and *A. racemosa* were isolated once each. *Isoachlya eccentrica*, reported as having been found once, was secured five times. A new species of *Pythiopsis* and a new species of *Leptolegnia* were taken several times each. *Dictyuchus*, non-fruiting cultures, was isolated twice. *Aphanomyces stellatus* and *A. laevis* occurred a few times. *Allomyces arbuscula*, described as having been found once in Chapel Hill, was discovered twice in the soil. *Pythium monospermum* and *P. deBaryanum* were the only *Pythium* species isolated, these two forms being more abundant than any other form except a certain Ascomycete, which the writer did not attempt to identify. *Olpidiopsis* species were found on two occasions parasitizing *Achlya* and *Aphanomyces*.

The most important finds were two new species of molds belonging to a remarkable new genus of the true water molds, *Saprolegniaceae*, but differing so widely from the other known genera as to occupy an entirely new section in the family. The new genus is described in this paper by Dr. Coker and the new species by him and the collector jointly.

Geolegnia Coker, n. gen.

Mycelium of very limited growth, forming a dense, opaque mat; hyphae very slender. Sporangia inflated at regular intervals or seg-

mented into two or more compartments (unless very small); spores in a single row, very large, encysting within the sporangium with a thick wall and without any motile stage; escaping by the decay of the thin-walled sporangium and sprouting by a germ tube. Oogonia abundant, even, containing a single eccentric egg that does not fill the cavity. Antheridia always present and androgynous.

In regard to the sporangia and spores this is the most peculiar genus of the *Saprolegniaceae* and it must occupy a section of its own. The peculiar sporangia and the large motionless spores with thick walls separate at a considerable distance all the other genera.

Geolegnia inflata Coker and Harvey, n. sp.

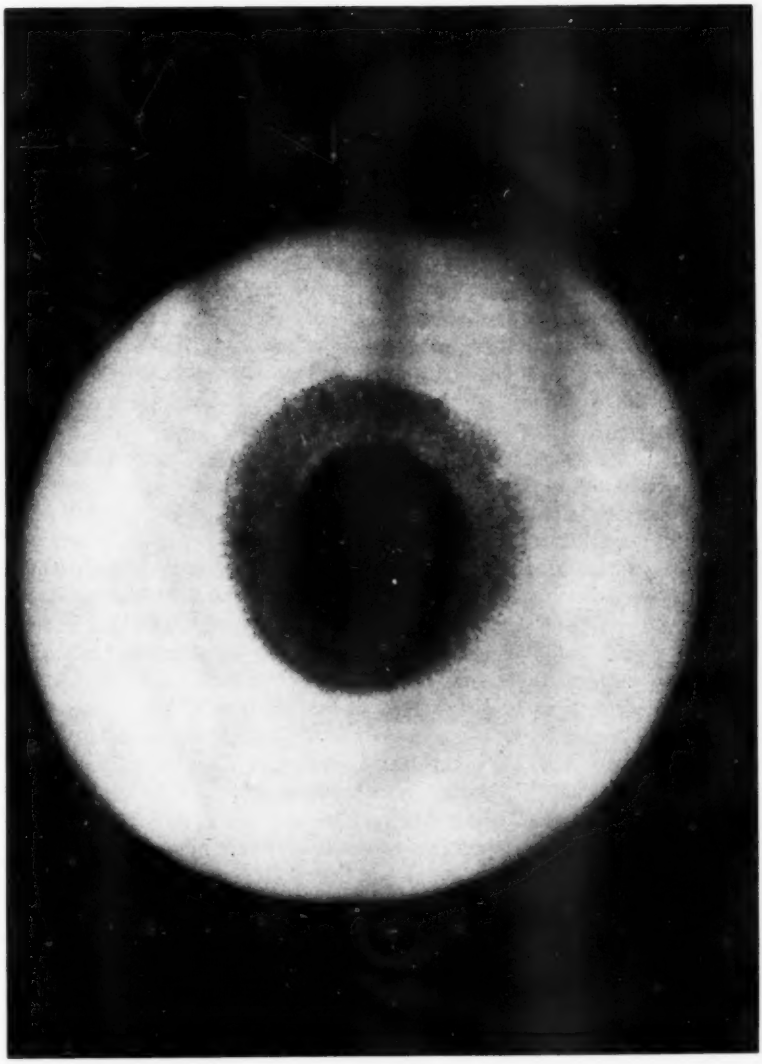
Plates 12–15

Mycelium of great density and slow and limited growth, as noted under the genus, forming after a few days a very dense, quite opaque, white mat, with individual threads distinguishable only on the margin. Growth on boiled hemp seed up to 2 mm. in six days, never reaching a length (ring growth) of over 3 mm. Hyphae straight, sparingly branched at first and then resembling *Leptolegnia*, 2.3–16μ thick. Primary sporangia formed from the straight ends of the larger hyphae, soon (usually before abstriction) becoming swollen at regular intervals; swellings 15–21μ thick; secondary sporangia, usually shorter, formed immediately below old ones, on the same thread or from lateral threads of irregular position. Spores very large and peculiar, spherical to oval, mostly spherical, rarely elongated, 3–15 to a sporangium, usually 4–6, formed singly in each swelling, 14–21μ thick, encysting in position with a thicker wall than that of the sporangium (0.5μ) and without any motile stage, escaping from the sporangium by decay of the delicate walls, which soon occurs; sprouting promptly when brought into new media. Oogonia abundant, spherical, 15–19μ thick, with thick (2μ), smooth, unpitted walls, usually appearing later than the sporangia, though occasionally earlier, borne singly and apically on smaller and more irregular branches than the main hyphae. Eggs one to each oogonium, 13–15μ, eccentric, with one large lateral oil drop. Antheridia, short, swollen, tuberous, always present, borne on slender, irregular often contorted branches which are mostly androgynous from near the oogonia, rarely diclinous.

Found three times: November 11, 1924, in fairly dry sandy loam, at a depth of four inches, at foot of cedar tree; again February 21, 1925, 11 miles south of Chapel Hill in a cedared pasture at a depth of one inch in loamy soil; also March 20, 1925, together with the next species, in dark sandy soil, under moss at the foot of a hickory two inches deep in a pasture. Kept growing continuously from single spore culture. Drawings made from these cultures.

In the early stages the plant resembles *Leptolegnia*, but is soon to the

PLATE 12



GEOLEGNIA INFLATA

A microphotograph of the entire plant as seen growing on a bit of hemp seed. × 6.

naked eye distinguished by the dense mat. The mat owes its density to the very large number of oogonial and antheridial branches, with many oogonia, and to the abundant (though fewer) sporangia. Oogonia first appear when the plant is two or three days old and require about 15 days for the eggs to mature. The plant is hardy, surviving well through bacterial infections. Spores will sprout and grow into new plants in the presence of bacteria, but progress is hindered to a great extent.

The portion of a thread which is to become a sporangium, normally straight and cylindrical, becomes swollen at regular intervals, from the tip back, from 75μ to 300μ, the protoplasm becoming denser at these points and less dense in the narrow spaces between the swellings. The swellings become larger, the protoplasm rounds up, the small strands connecting the swellings now disappear, the rounded masses become smaller and shrink away from the sporangium wall. The sporangia are cut off from the main hyphae by a septum formed usually at the time when the swellings reach full size and just prior to spore formation, sometimes before swellings occur. After the formation of spores secondary sporangia may be formed below or by lateral branching. Primary sporangia are formed at the tip of nearly every thread within one day. Unless transferred to new media the spores in a dormant state float around indefinitely in original cultures.

It is of interest to note that the spores and oogonia are usually about the same size, or often the spores are larger than the oogonia. The spores have a distinct clearer central region as described in the conidia of *Pythium* species. The spores sprout on corn meal agar, but growth of mycelium is very slow, a few sporangia being formed. It is several days after a piece of hemp seed is placed on a block of agar in water containing the mycelium that the hemp will be obviously inoculated. The plant grows well in distilled water on hemp seed, not so well on corn, fairly well on boiled and unboiled sweet potato and Irish potato, also on rye and a little growth has been noted on rice.

Geolegnia septisporangia Coker and Harvey, n. sp.

Plate 16

Mycelium exactly as in the preceding species except of even more limited growth, forming after a few days a dense, opaque mat with individual threads distinguishable only at the edge of the mat. Growth on boiled hemp seed up to 2 mm. in five days, but never reaching a length (ring growth) of 3 mm. Primary sporangia formed at the ends of practically all hyphae, these and later ones usually divided into several

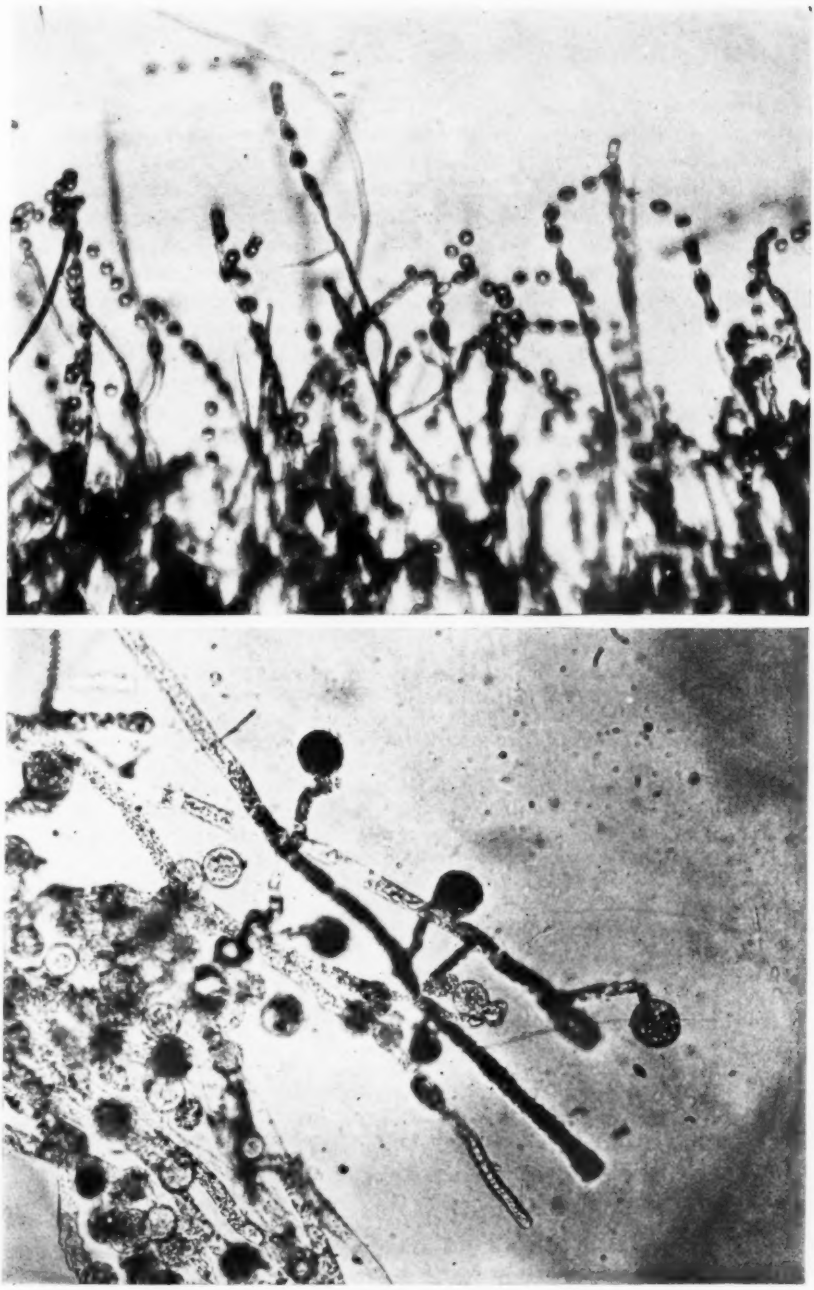
cells by cross partitions after being cut off and just before the spores are formed; swollen at places, but not so often nor so greatly and regularly as in the preceding species, 11.8–21.15μ thick and up to 136μ long. Secondary sporangia formed at the tips of lateral branches somewhat as in *Achlya*. Spores very large and peculiar, rarely spherical, mostly oval to ovoid or elongated, formed in a single row, 1–15 to a sporangium, usually 2–5, 11.8–2i x 20.3–56.4μ, encysting within the sporangium with a rather thick wall (0.9μ) and never escaping from the sporangium except by the decay of the walls. On change of conditions, as removal to corn meal agar, sprouting at once by a germ tube; never forming swarm spores. Oogonia abundant, appearing very suddenly in young and old cultures alike and without apparent cause, borne singly and apically on smaller branches than the main hyphae; subspherical, 22–34μ thick; wall smooth, thin, colorless. Eggs one to each oogonium, spherical to slightly oval, 20–32μ thick, eccentric, with one large lateral oil drop; walls very thick, 2μ. Antheridia always present, elongated and apically attached to the side of the oogonium, in all cases observed borne on short, irregular androgynous branches from the oogonial stalk at a little distance below the oogonium, 1–4 attached to each oogonium. Emptying of antheridial contents into egg observed.

Found twice: March 4, 1925, in dry sandy iron-loam soil, near the old iron mine, at a depth of one inch, at the foot of an oak tree; again March 20, 1925, in dark sandy soil at a depth of two inches, under moss at the foot of a dead hickory, in a pasture by a branch, this time growing together with the preceding species.

The mycelial mat appears to the naked eye like that of the preceding species, very dense and opaque and is formed in the same way by the close interlacing of oogonial and other lateral branches. The plant is hardy and survives ordinary bacterial infections easily. The spores sprout readily on agar, even more quickly and growing on agar better than those of the first form. Sprouting spores have been found also in water cultures.

The young sporangia often resemble those of *Saprolegnia* and *Achlya* species as to shape and in the possession of a central vacuole, but are very much smaller. At other times the sporangia are straight and cylindrical. The primary sporangia are formed at the tips of the hyphae, and are densely filled with protoplasm just before they are cut off. A somewhat elongated central vacuole occurs, which becomes broken up into smaller vacuoles as the spore origins are formed. Spores are formed by the inward growth of vacuolate furrows, the spores appearing to be pinched off inside the sporangium. The septum does not change either to convex or concave inward after the spores are formed, as it does in the sporangia of species of *Saprolegnia*, *Achlya*, etc., but remains in the same

PLATE 13



GEOLEGNIA INFLATA

(*Above*) Microphotograph of a portion of the plant on hemp seed, to show sporangia. × 37. (*Below*) Microphotograph to show the relation of the oogonia to the hyphae and sporangia. × 123.

position. The frequent formation of cross walls in the sporangium initials after their separation from the hyphae is a remarkable peculiarity that is found in no other member of the family. For this reason and also for the fact that the spores are formed simultaneously in all the cells it would seem more correct to call the resulting row of cells a compound sporangium rather than a row of separate sporangia. In other water molds when sporangia occur in rows the spores are formed consecutively, beginning with the apical and the oldest one. The cross walls are all much thicker than the extremely thin lateral wall of the sporangium and they are usually so close to the nearest spore below as to appear much like a shining cap on its distal end.

Oogonia appeared suddenly within the same two days in old and young cultures three weeks after the plant had been collected the first time. This late appearance of oogonia in the older cultures may possibly have been due to the presence of cooler weather during the Easter holidays, following the warmer period when the plant was collected. However, cultures grown in an ice box since have produced no oogonia.

Pythiopsis intermedia Coker and Harvey, n. sp.

Plates 17 and 18

Vegetative growth of long, slender, sparingly branched hyphae, 11–14μ thick which are stoutest in the neighborhood of the reproductive bodies, and which after maturity disorganize rather quickly. Sporangia very variable, the majority elongated, irregular and tapering to a long crooked papilla, varying to spherical, proliferating from below in a cymose manner; spores diplanetic, pear-shaped, 8–11.8μ long. Oogonia formed after two days, generally borne like the sporangia and not easily distinguished from certain forms of these when young, usually on short or long, irregular and often coiled lateral branches and often in groups by cymose branching, usually irregularly subspherical with a short basal neck, 35–50μ thick, usually about 35–45μ; wall wavy with low irregular protrusions. Eggs generally one, rarely two, three or four, subcentric with two layers of oil droplets on one side and one on the other, as in *Saprolegnia asterophora*, etc., 23–33μ thick; wall about 3.5μ thick. Antheridia as in *P. cymosa*, short-clavate and terminating a stalk that usually arises from immediately below the oogonium (sometimes of more distant origin, and rarely diclinous), or formed in immediate contact with the oogonium base and growing out laterally along its surface, usually one to an oogonium, rarely two; antheridial tube obvious, reaching and apparently fertilizing the egg. Gemmae resembling sporangia and oogonia abundant and forming spores after a rest.

Taken three times in 200 collections: November 13, 1924, from Forest Theatre, on hillside in front of the stage at a depth of nine inches

in sandy soil (loam) at the foot of a post oak; again December 17, 1924, in sandy loam soil one inch deep on a hilltop at the foot of a very young pine; also February 19, 1925, in the Arboretum at a depth of one inch in loamy soil at the foot of a beech tree.

The present species resembles *P. Humphreyana* in habit, size and shape of the sporangia and in the size of the oogonia, but differs markedly in the frequent occurrence of basal antheridia and in the irregular and wavy oogonial wall. It resembles *P. cymosa* in the presence of oogonia with wavy walls and in the frequent close contact of the antheridia to the oogonia, which causes the oogonia to appear to rest at maturity on a large, swollen, basal cell. It differs from that species in the larger oogonia and structure of the egg and in the regular occurrence of long, tapering sporangia.

The diplanetic spores (a character that has been thoroughly checked) introduce a troublesome variation into the genus *Pythiopsis* and require a modification of its diagnosis to include both types of behavior. It is obvious that the plant cannot be placed in any other genus as now accepted, and the obvious resemblance to the other two species of *Pythiopsis* make it preferable to put the species in that genus.

Leptolegnia subterranea Coker and Harvey, n. sp.

Plate 19

Mycelium on hemp up to 15 mm. in five days. Hyphae sparingly branched, just enough for the plant to appear as a delicately matted growth, with the threads distinguishable practically throughout their length, 9.4–11.8μ thick. Sporangia filamentous, of the same size as the hyphae, often long but not so long as in *Aphanomyces*, about 11.8μ broad and up to 785μ long or longer, sometimes branched, in which case all the spores may emerge through a common mouth at the apex of the main trunk or any branch; spores typically in a single row, spherical or oval to elongated, there being about as many of one form as another, 11.8μ broad and up to 16.4μ long; diplanetic, swimming away upon emerging, after encysting measuring up to 14.1μ thick. Oogonia abundant, spherical or subspherical to irregular, usually with low or high, blunt or pointed and irregular protrusions, which may reach a length of 9.5μ, oogonia without the protrusions 40–51.7μ; wall about 1.3μ thick. Eggs one to an oogonium and filling it completely, the mature egg with a cup of oil globules on one side; the wall extremely thick, about 3.7–5.5μ, rarely 6.5μ. Antheridia lacking in all our cultures.

Taken eleven times in 200 collections: five times in sandy soil, twice in sandy humus, twice in loam, once in clay loam, and once in sand, at depths from 1–12 inches, both wet and dry situations (see table).

Sporangia are formed in one day, emptying mostly at night, most of the spores observed emptying after 10 p.m. The spores upon emergence reshape themselves as in *L. cordata* and swim away in the usual form. Unlike *L. cordata*, a large number of spherical spores are often present in the sporangia mixed with the elongated ones.

Oogonia are formed within 4–6 days. Only a few have smooth walls; most have a few to many projections. Immature oogonia may proliferate, as in species of *Achlya*, by the elongation of one of its projections which swells at the tip to form a secondary oogonium into which the contents of the first passes over into the new. The new oogonium may in turn give rise to another in a similar manner. In one

TABLE I

Leptolegnia subterranea

DATE	NUMBER	KIND OF SOIL	VEGETATION	DEPTH
				inches
11-11-24	106	Damp sandy loam	Alder	2
11-24-24	133	Damp clay loam	Pine	2
12-16-24	139	Damp sandy loam	Alder	2
12-17-24	151	Damp sand	Pine	2
2-19-25	237	Damp loam	Beech	1
2-21-25	246	Damp sand	Moss	3
2-21-25	249	Wet loam	Sphagnum and liverworts	1
3- 4-25	259	Dry red clay	Grass	4
3-20-25	271	Dry sandy loam	Pine stump	2
3-21-25	279	Very dry sandy humus	Pine	1
2-19-25	239	Damp loam	Beech	1

respect the egg behaves in a very remarkable manner. As maturation begins (as indicated by the formation of its own wall) the protoplasm does not organize itself into an obvious egg with a new and even surface, but continues to fill all the projections and irregularities of the oogonium so that the egg wall when fully formed extends into all the protrusions, completely filling all but the larger ones. Into these larger projections and bulges the protoplasm extends and makes no effort to form a symmetrical body.

The plant grows best on bits of hemp seed and corn meal agar. Drawings were made from single spore cultures. Table I gives the collection data for *L. subterranea*, omitting the locations.

Saprolegnia ferax was found once in 200 collections of soil. The species grew vigorously on corn meal agar and bits of hemp seed, behaving normally, as if the plant had been taken from water: sporangia and sexual bodies were formed in abundance. Found November 14, 1924, in sandy loam soil, at a depth of six inches, around the roots of a young pine in a grassy meadow, beyond Cobb Terrace. The soil was dry at the time.

TABLE II

Achlya caroliniana

DATE	NUMBER	KIND OF SOIL	VEGETATION	DEPTH
				inches
11-11-24	109	Sand and clay	Grass	2
11-11-24	110	Sand and clay	Grass	5
11-13-24	112	Sandy clay loam	Alder	6
11-14-24	130	Loam	Honeysuckle	2
11-29-24	131	Loam	Corn	2
12-16-24	141	Sandy loam	Alder	12
12-17-24	142	Sandy humus	Spanish oak	2
12-17-24	148	Loamy humus	Moss	4
12-17-24	149	Damp red clay	Pine	3
12-17-24	150	Damp red clay	Pine	6
12-17-24	152	Wet sand	Moss	1
1- 7-25	169	Dark sandy	Periwinkle	2
1- 7-25	170	Dark sandy	Periwinkle	5
1- 8-25	177	Clay	Privet	1
1- 8-25	178	Clay	Privet	4
1- 8-25	179	Sandy loam	Cedar	1
1- 8-25	180	Sandy loam	Cedar	10
2- 4-25	212	Sandy manured	Hedge	1
2- 4-25	218	Sandy manured	Hemlock	3
2- 4-25	219	Sandy manured	Hemlock	7
2-13-25	230	Loam		4
2-19-25	232	Loam	Incense cedar	4
2-19-25	233	Loam	Photinia	2
2-19-25	234	Loam	Photinia	6
3-12-25	261	Sandy loam	Sweet breath of spring	2
3-12-25	262	Sandy loam	Sweet breath of spring	7
3-20-25	275	Sandy loam	Grass	7

Isoachlya eccentrica has heretofore been reported only from the type station in water (2, p. 87). During the fall and winter months we have found the plant five times in soil and once in water from a marsh on Glen Burnie farm. Since November, 1924, it has been found in soil

collections from the Arboretum, the Forest Theatre (open woods), and the new athletic field. It was found twice in sandy loam, once in manured soil, and twice in clay soil, at depths from 3 to 7 inches. Found growing with *Achlya caroliniana*, *Pythium deBaryanum*, and *P. monospermum*. The plant corresponds identically with the original description.

Achlya caroliniana has been taken 27 times in 200 collections. There seems to be no regularity of occurrence as to the kind of soil, nor does it seem to have any relation to the higher plant life, under which it is found. This form and *A. flagellata* were found often together, as well as with other Phycomycetes. Table II gives the collection data for *Achlya caroliniana*.

TABLE III

Achlya flagellata

DATE	NUMBER	KIND OF SOIL	VEGETATION	DEPTH
				inches
11-14-24	124	Dry sandy loam		4
11-14-24	125	Wet coarse sand	Grass	2
11-16-24	141	Damp sandy loam	Alder	12
12-17-24	152	Wet sand	Moss	2
2- 4-25	211	Dry sandy loam	Hedge	1
2- 4-25	212	Dry sandy loam	Hedge	3
2- 4-25	213	Dry sandy loam	Hedge	7
2- 4-25	214	Dry sandy loam	Wisteria	1
2- 4-25	219	Dry manured loam	Hemlock	7
2-13-25	240	Loam		4
2-19-25	241	Loam	Incense cedar	1
2-19-25	242	Loam	Incense cedar	4
2-19-25	243	Loam	Photinia	2
2-19-25	244	Loam	Photinia	6
3- 4-25	251	Loam	Corn	3
3-31-25	289	Sandy clay loam		3

Achlya flagellata has been isolated from the soil 16 times in 200 collections, according to table III.

Achlya hypogyna and *A. racemosa* were found only once each, and that in the same collection with *A. caroliniana*, *Leptolegnia*, and *Pythium monospermum*. Taken from sandy soil, at a depth of one inch, from the stage of the Forest Theatre, under a young cedar.

Thraustotheca clavata. This species has been taken six times in 200 collections. It is interesting to note that this plant occurred only in grassy soil that had become packed, as in the Arboretum and an orchard at Glen Burnie farm. It was found at a depth of one to four inches.

Allomyces arbuscula has been reported once from India, once from the Philippines and twice from the United States (2, p. 182). We have found it twice: February 4, 1925, in the Arboretum, 3 inches deep in fairly dry manured soil, under hemlock; again February 13, 1925, in frozen dark loam, 6 inches below the surface on the face of the excavation for the new Methodist church.

Dictyuchus sterile has been isolated from the soil twice: November 14, 1924, in dry sandy loam around roots of honeysuckle near surface of ground in a pasture beyond Cobb Terrace; February 21, 1925, in wet sandy soil, 3 inches deep, by side of highway, at Lakeview, N. C. No other forms were found with this.

Aphanomyces laevis was discovered once in the soil: March 12, 1925, from dry loam, at a depth of six inches, in the Arboretum, under holly-leaved olive, the ground being covered with leaves.

Aphanomyces stellatus occurred three times in the earth: December 17, 1924, 8 inches deep in sand, by a pine stump; also on January 8, 1925, from sandy loam near the surface under a cedar.

Olpidiopsis species was found twice: Once parasitizing *Achlya*, December 16, 1924, from damp sandy loam 8 inches deep under a cedar. Before accurate data were kept it was found once parasitizing *Aphanomyces.*

Pythium deBaryanum was found 38 times in 200 collections between November 11, 1924, and April 13, 1925. It occurred at depths of 1–12 inches in all kinds of soil, mostly damp or wet sand, sandy loam, clay, humus, and in the neighborhood of many kinds of plants.

Pythium monospermum was found 30 times in 200 collections and like *P. deBaryanum* appeared in many kinds of soil, mostly damp or wet, and with a variety of vegetation.

SUMMARY

1. It has been found for the first time (two parasitic species of *Aphanomyces* excepted) that many species of the *Saprolegniaceae* are contained in the soil, and that some are much more common in the soil than in water. Nearly all the soil taken at depths down to six inches have been found to contain water molds and they are common at a much greater depth.

2. A peculiar new genus, with two species, is described, and two other new species of established genera have been found.

3. These soil forms, except in the case of the new genus, when cultured produce sporangia which give rise to swimming spores, as found in the water forms. Sexual bodies are produced in abundance.

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EXPLANATION OF PLATES

PLATE 14

GEOLEGNIA INFLATA

Figs. 1–6. Various stages in the development of the sporangia. × 450.
Fig. 7. Mature sporangium. × 450.
Fig. 8. Sprouting spore. × 450.
Fig. 9. Habit sketch to show the branching, oogonia, and sporangia. × 60.
Fig. 10. Spore. × 975.

PLATE 15

GEOLEGNIA INFLATA

Figs. 1–4. Various stages in the development of the oogonia. × 950.
Fig. 5. Portion of plant to show the relation of the sexual bodies to the sporangia. × 640.
Fig. 6. Portion of the plant to show relation of oogonium to hypha. × 950.

PLATE 16

GEOLEGNIA SEPTISPORANGIA

Figs. 1–5. Stages in the development of the sporangia. × 450.
Figs. 6–9. Stages in the development of the oogonia. × 950.
Fig. 10. Portion of plant to show the relation of a sporangium and an oogonium. × 450.
Fig. 11. Habit sketch of the plant to show sympodial branching. × 250.
Fig. 12. Spore. × 975.

PLATE 17

PYTHIOPSIS INTERMEDIA

Figs. 1–6. Various types of sporangia. 1, 3, and 5 × 270. 2, 4, and 6 × 750.
Fig. 7. To show relation of an oogonium to a sporangium. × 95.
Fig. 8. Diplanetic spores. × 825.

PLATE 18

PYTHIOPSIS INTERMEDIA

Figs. 1–4. Various stages in the development of oogonia and antheridia. × 412.
Figs. 5–8. Various stages in the development of the egg. 5, 6, and 7 × 412. 8 × 675.
Figs. 8–10. Oogonia to show mature eggs. 9 × 412. 8 and 10 × 675.
Fig. 11. To show oogonium with three small immature eggs. × 412.
Fig. 12. To show cymose branching of oogonia. × 250.
Figs. 13 and 14. To show oogonia with typical gnarled stalks. × 412.

PLATE 19

LEPTOLEGNIA SUBTERRANEA

Figs. 1–3. Types of sporangia. × 412.
Fig. 4. Sporangium to show sprouting spores. × 412.
Figs. 5–8. Various forms of mature oogonia. × 412.
In figure 5 the structure is abnormal and the egg is probably dead. The clear area between the egg protoplasm and the oogonial wall represents the egg wall, in these figures and in fig. 11.
Fig. 9. To show surface view of an oogonium. × 412.
Fig. 10. An oogonium with a somewhat elongated protrusion. × 675.
Fig. 11. An oogonium with a mature egg which has been killed by the preserving fluid. This has caused the separate droplets to fuse into one. × 412.
Fig. 12. An oogonium from which a protrusion has grown to form at its tip a secondary oogonium. × 412.

PLATE 14

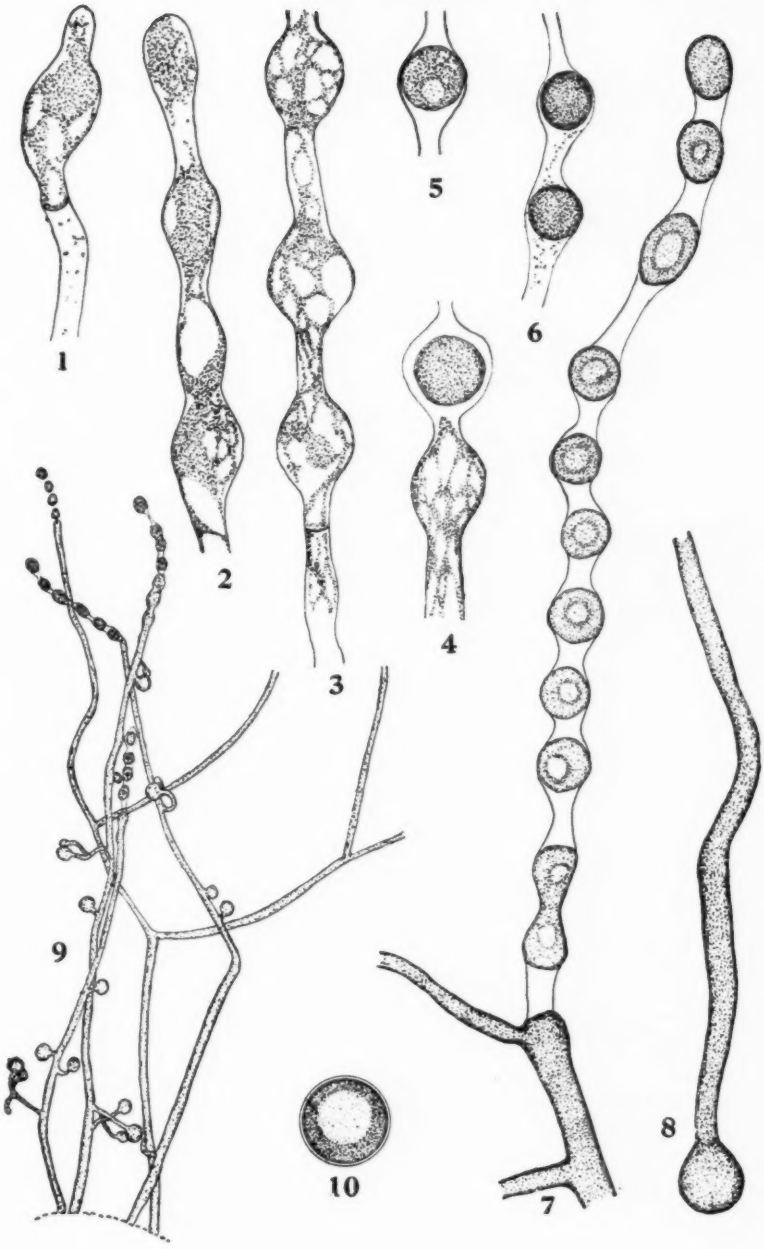


PLATE 15

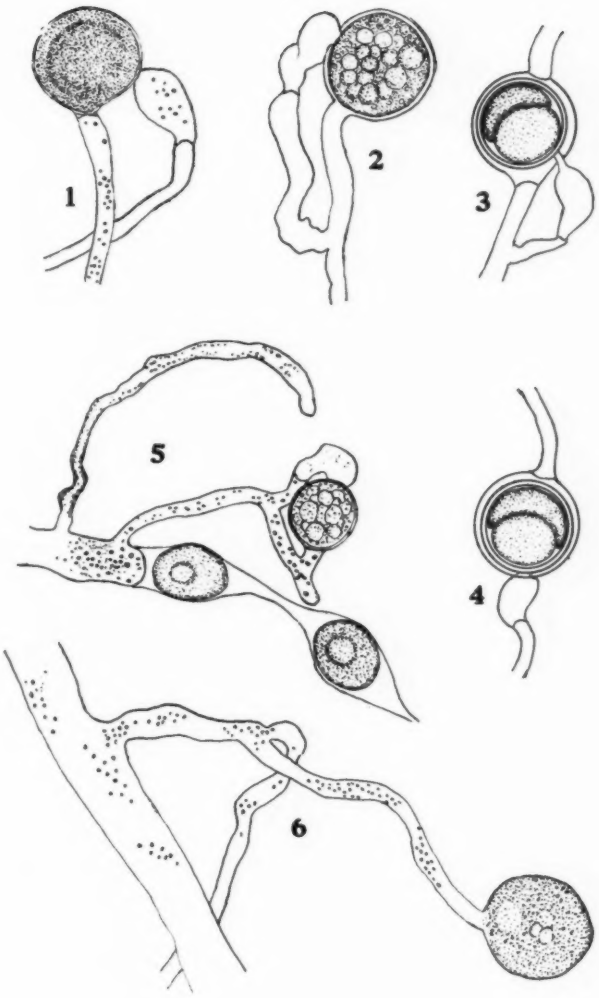


PLATE 16

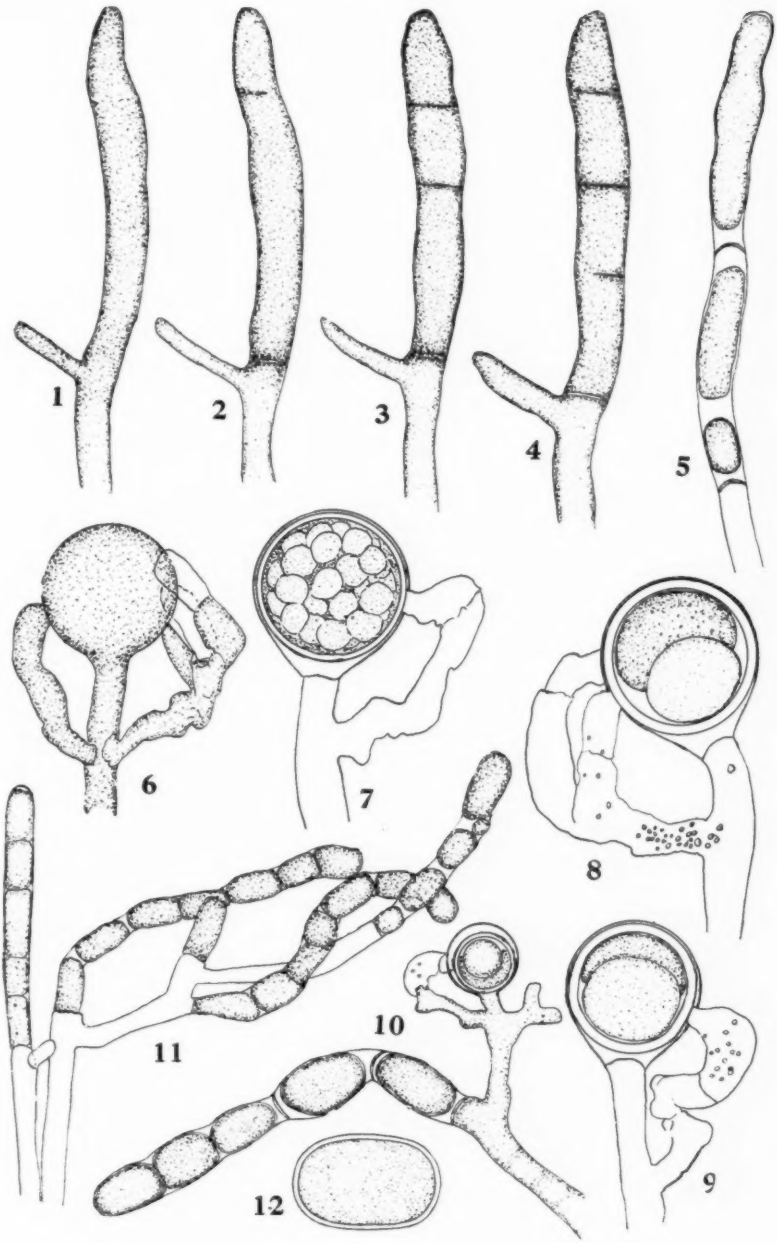


PLATE 17

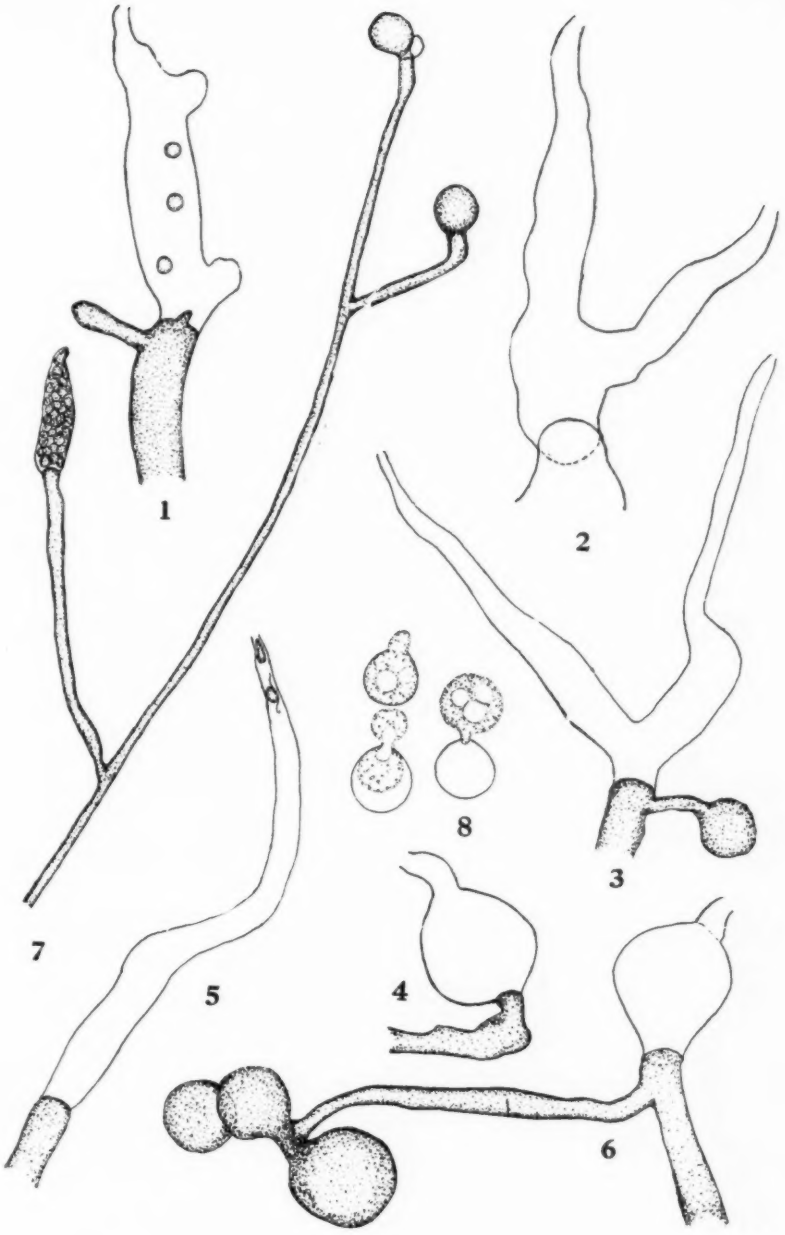


PLATE 18

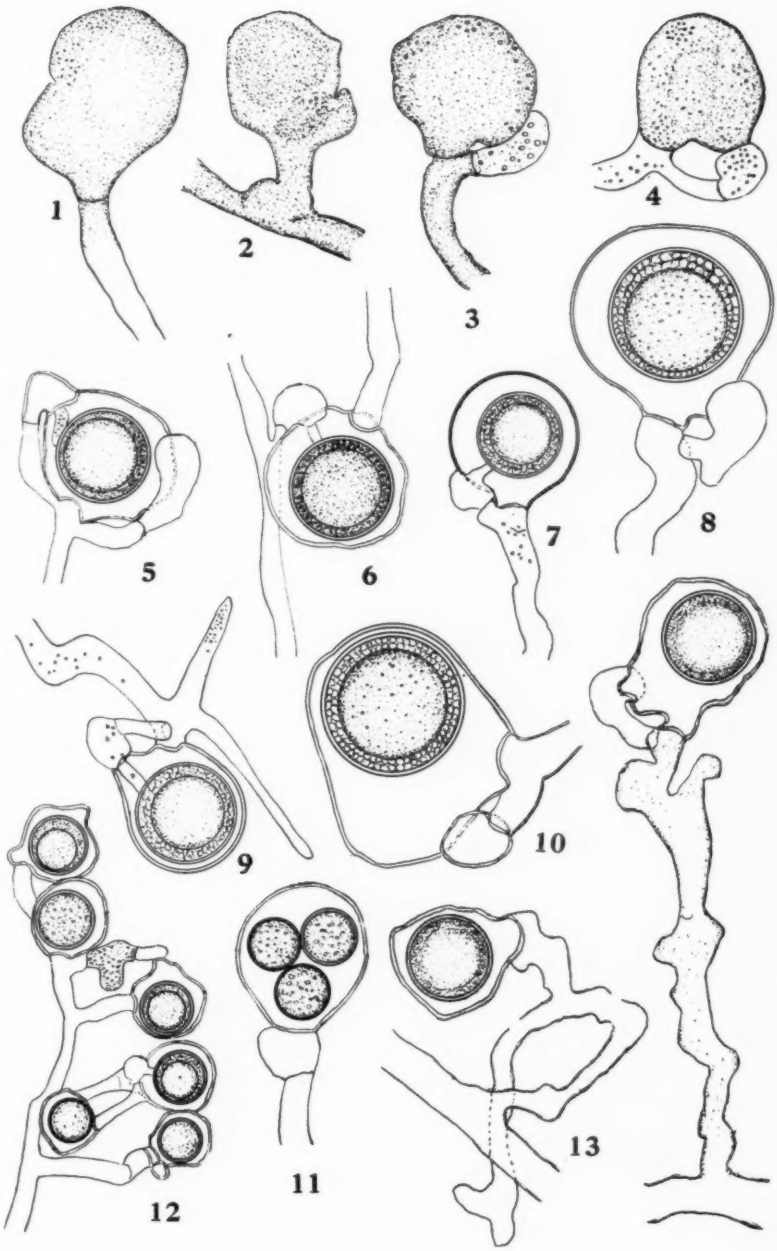
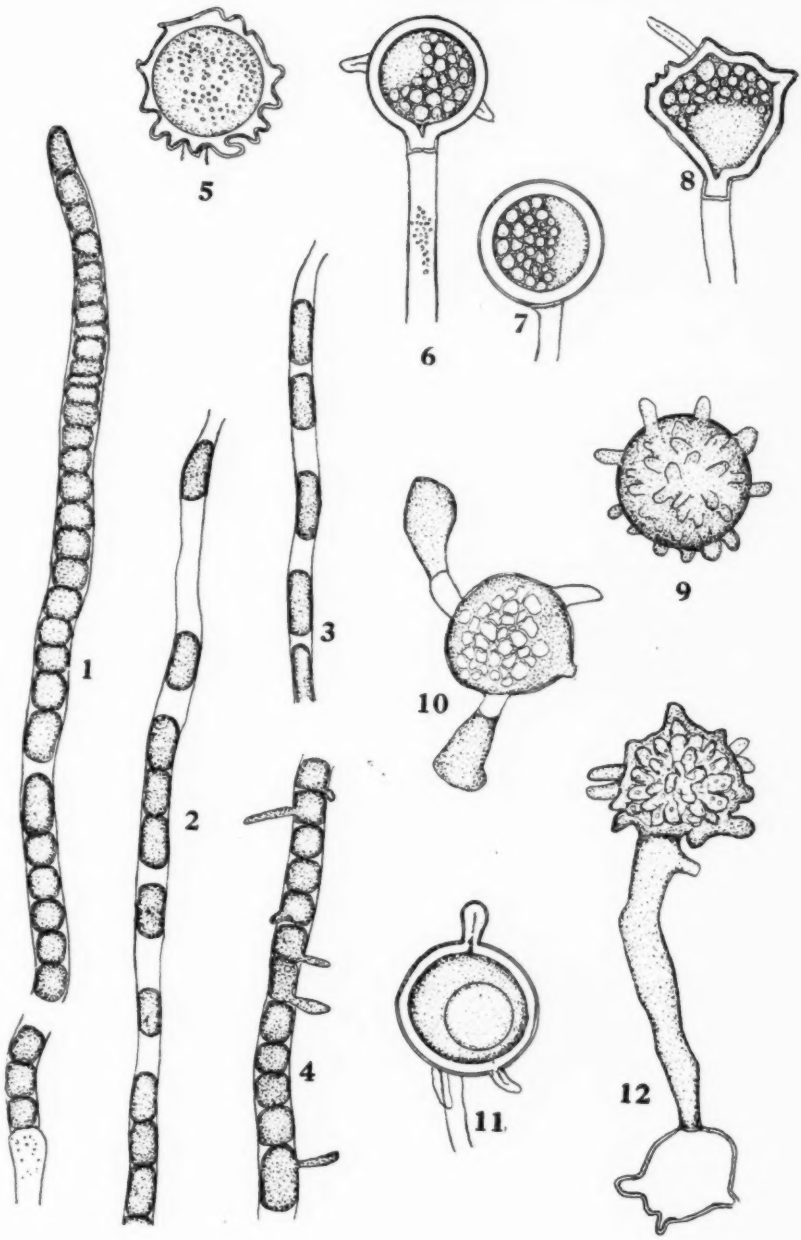


PLATE 19



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